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TEXT BOOK

OF

PHYSIOLOGY.

A

TEXT BOOK

OF

PHYSIOLOGY.

BY

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SECOND EDITION, REVISED AND ENLARGED,
WITH NUMEROUS ILLUSTRATIONS.

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PREFACE TO THE SECOND EDITION.

The science of Physiology has been so much advanced in almost every department of the subject, since the issue of the first edition, that the preparation of the present one has been no easy matter. The very favorable reception, however, which was accorded the first edition, has induced me willingly to undertake the self-imposed task. Many of the chapters have been re-written, and much new matter added; but while every part has received careful revision, the original plan of arrangement has been rigidly adhered to, as that best adapted to the wants of those for whom it was written.

My experience as a teacher in the department of Physiology during the last fifteen years, formerly in Victoria Medical College, and latterly in the University of Trinity College, has led me to the conclusion that Physiology can be best taught in connection with Histology, and with this view I have endeavored to supply a prevailing want in the ordinary text books, by the introduction of a concise history of this interesting subject. It has been truly said that a knowledge of Anatomy is the keystone to Medicine, and it is equally true that a knowledge of Histology is the keystone to Physiology.

Illustrations have been introduced wherever they appeared desirable, and in order to prevent the volume from being too expensive, such illustrations as did not appear necessary to the elucidation of the text have been omitted.

The illustrations are partly new and partly borrowed from recognized authorities, and special acknowledgment must be made of those obtained from JAMES CAMPBELL, Publisher, Boston, U.S. It was not considered desirable, as a rule, in a work of this kind, to quote authorities for the statements in the text, as it would have required numerous references to home and foreign books and periodical literature, which would have been not only useless, but confusing to the generality of readers.

Notwithstanding the number of most excellent works on Physiology published, a well digested text book on this subject, adapted to the wants of the advanced medical student and the general practitioner, is still a desideratum in medical literature. This work is chiefly intended for medical students, but it is hoped that it may also prove serviceable to medical practitioners, more especially those who have students under their instruction.

J. FULTON.

ELGIN PLACE, 303 Church St., Toronto.

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HUMAN PHYSIOLOGY.

INTRODUCTION.

Physiology, from φυσις, "nature," and λογος, a description," in its general sense, has for its province the investigation of the active phenomena presented by organized bodies, and is divided into two parts, viz:—Animal, and Vegetable Physiology: the former treats of the laws that control the Animal Kingdom; the latter relates to those of the Vegetable Kingdom. Animal Physiology may also be divided into two parts, viz: Human Physiology, and Comparative Physiology, or the Physiology of the lower animals.

Human Physiology treats of the vital phenomena of the human species, and is of much more practical importance to the medical student than the Physiology of the lower animals, on account of its relation to Pathology and Therapeutics. The study of Physiology requires an intimate knowledge of Anatomy and Chemistry, in order that the student may be able to comprehend the character of the structure he is examining, and the substances of which it is composed.

Animate bodies, in contradistinction to inanimate, are possessed of organs, each of which has a special structure and distinct office to perform in the living organism. This action or office is called its *function*, for example, the function of the liver is to secrete bile, the salivary glands to secrete saliva, &c. The functions of the different organs are also mutually dependent on each other. The aëration of the blood by the lungs, is dependent on its circulation by the heart and blood vessels, and the circulation of the blood

is dependent on the influence of the nerves, and the continuance of life is the result of the continued normal and harmonious action of all the organs of the body.

The different organs of the body are sometimes called systems, as the osseous system; muscular system; nervous system; arterial system, etc. Each organ is made up of smaller parts or ultimate elements, which can only be seen and studied by the aid of the microscope; these are called the "anatomical," "histological," or "microscopical elements; for example, the primitive fibrillæ are the ultimate or "anatomical" elements of muscular tissue, the axis cylinder and white substance of Schwann are the anatomical elements of nerve fibres, etc.

All living beings pass through the various stages of birth, growth, development, maturity, and decay. These are the so-called essentials of life. Birth means the separation from the parent, with power of independent life and existence, inherited from the parent. Growth is the power of increasing in size, but this is not limited to living beings. A stone or a crystal may also grow, but it is by the laying on of particles on the outside, or *superficial*, while the growth of living organisms is *interstitial*, and has definite limits. Living organisms absorb the material required in growth into their interior, and assimilate it into their own composition. Development indicates the successive changes through which all living organs must pass, before they are capable of properly performing their functions. The brain of the adult idiot has grown, but it is incapable of the proper performance of its function, from want of proper development. Maturity is the attainment of complete growth, and is soon followed by decay or decline. In fact, decay may be said to be constantly taking place in our bodies, and life consists in making up for the loss attendant on it, by continual repair. The particles of our bodies die, and are replaced by new ones from day to day, although the individual remains the same, so that it may be said of our bodies "in the midst of life we are in death."

Some have endeavoured to draw a distinction between the animal and vegetable kingdoms, but while this is a matter very easy of accomplishment in the higher orders, it is very difficult to say where vegetable life terminates and animal life begins, lower in the scale. The distinction which is probably the most reliable, is the power of vegetables to live on *inorganic* matter, as water, carbonic acid, and ammonia, while animals cannot subsist without organic material. The distinctions sometimes given, based on the difference in chemical composition—the presence or absence of nitrogen; the power, or absence of movement, and the presence or absence of a stomach in animals and vegetables respectively, while of value so far as the higher orders are concerned, are valueless as a means of distinguishing between the two classes, low down in the scale of life.

CHAPTER I.

PROXIMATE PRINCIPLES.

Animal bodies are composed of solids and fluids: the former embrace the various textures and viscera; the latter the blood, chyle, lymph and glandular secretions. The same substance may be fluid in one part of the body and solid in another; for example, lime phosphate is in solution in the albumen of the blood, but is solid in the bones. Every animal tissue and fluid contains a number of proximate principles mingled together in various proportions.

A proximate principle may be defined to be any chemical substance, which exists in the animal solids or fluids in its own form, and which may be extracted in an unaltered state by chemical process.

But it must not be supposed that every substance which can be extracted from an organized solid or fluid by chemical means is a proximate principle; for example, sodium chloride is a proximate principle; but chlorine is not, because it does not exist in its elementary form in the body. Lime phosphate is a proximate principle of bone; but phosphoric acid is not, because it does not exist in a free state in the bony tissue; still less phosphorus, which is obtained only by the decomposition of phosphoric acid. Again, fibrous tissue, when boiled steadily for thirty-six or forty hours, yields a substance called gelatine; but this is not a proximate principle, since it does not exist as such in the body but is produced only by long-continued boiling.

In extracting the proximate principles from the animal body, only the simplest chemical means should be employed. First, evaporate the substance, to extract and estimate the

amount of water. The temperature should not be above 100° (212°F.) because a higher degree would change some of the animal ingredients. Then dissolve out the salts with water.

Coloring matter, or pigments, may be extracted by alcohol; oils and fats by ether. Some of the salts may be removed by double decomposition. Thus, sodium glyko-cholate or tauro-cholate may be precipitated by lead acetate, forming lead glyko-cholate or tauro-cholate which may, in its turn, be decomposed by sodium carbonate forming the original sodium glyko-cholate or tauro-cholate. Sometimes a proximate principle cannot be separated in an entirely unaltered state. Albumen requires to be coagulated by heat or nitric acid; the fibrin of the blood can only be separated by coagulation, which it does spontaneously; hence they lose their original character of fluidity, and are permanently altered.

The proximate principles are divided into five classes:

1st. Crystallizable substances of inorganic origin, as water, sodium chloride, lime carbonate and phosphate, etc. They are derived mostly from exterior sources. They are found in organized as well as in unorganized bodies, and have a definite chemical composition.

(In this class may also be included the gases, as oxygen, hydrogen, nitrogen, carbonic acid, carburetted and sulphuretted hydrogen).

2nd. Crystallizable substances of organic origin, or non-nitrogenized substances, as starch, sugars, oils, and fats. They are found only in organized bodies, are crystallizable (excepting starch), and have a definite chemical composition. They contain carbon in large proportion but no nitrogen.

3rd. Organic substances proper, "nitrogenized substances," "albuminoid substances," or "protein compounds," as albumen, fibrin, casein, &c. They differ from the two former classes in the fact that they contain nitrogen. They are exclusively organic in their origin, are not crystallizable, and are not definite in their chemical composition.

4th. Coloring matters, as hemoglobine, melanine, bilirubine, biliverdine, etc.

5th. Crystallizable nitrogenous substances, as urea, creatine creatinine, lecithine, cerebrine, etc.

PROXIMATE PRINCIPLES OF THE FIRST CLASS.

WATER, H_2O.—Water is the most important of the inorganic principles, and is found in all parts of the body. In the solids it does not exist in a fluid state, but is incorporated with the substance of the tissue. It may be called "*water of composition*," in contradistinction to what is called in chemistry "*water of crystallization*." It constitutes about two-thirds of the entire weight of the body.

The following table shows the proportion of water per 1,000 parts in different solids and fluids :—

QUANTITY OF WATER IN 1,000 PARTS.

Solids.	Enamel of the Teeth....	2	*Fluids.*	Blood................	795
	Epidermis............	37		Bile................	880
	Teeth................	100		Milk................	887
	Bones................	130		Pancreatic Juice........	900
	Tendons..............	500		Urine................	936
	Cartilage..............	550		Gastric Juice..........	975
	Muscles..............	750		Perspiration..........	986
	Ligaments............	768		Saliva................	995

ORIGIN AND DISCHARGE OF WATER.—It is introduced with the fluid and solid elements of the food. It is also believed to be formed in the body from the union of oxygen and hydrogen, as they are liberated from organic combinations. The amount of water taken into the system by an adult, in the course of 24 hours. varies from $3\frac{1}{2}$ to 4 pounds. It is discharged from the body in four different ways—by the urine, fæces, perspiration, and breath—about 50 per cent. being discharged by the urine and fæces, 30 per cent. by the perspiration and 20 per cent. by the lungs. These proportions will vary according to circumstances; for example, in warm weather, when the skin is more active, and the perspiration more abundant, the quantity of urine is diminished. The

quantity of water discharged by the lungs varies also, with the state of the atmosphere and the pulmonary circulation. The water is not discharged pure, but is mingled with various salts, animal matters, and odoriferous substances.

FUNCTION.—It holds in solution different salts and substances of excretion, and gives fluidity to the blood and secretions. It is a most important article of diet, and is necessary both for the introduction of substances into the body, and their elimination from it. It gives to cartilage its elasticity, and to tendons their toughness and pliability, for, if water be expelled from a piece of cartilage by evaporation, it becomes dark in colour, semi-transparent, hard and inelastic. The same thing is true of muscles, tendons, etc.

SODIUM CHLORIDE, NaCl.—Sodium chloride is next in importance, and is found in all parts of the body except the enamel of the teeth. The entire quantity in the body has been estimated by Dr. Lankester, at one-quarter of a pound, avoirdupois. It exists in the greatest quantity in the fluids. In blood, for example, it is more abundant than all the other salines taken together. The following is a list of the quantities in the most important solids and fluids.:—

QUANTITY OF SODIUM CHLORIDE IN 1,000 PARTS.

Muscles	2	Lymph	5.
Bones	7	Blood	3.3
Milk	.3	Chyle	5.3
Saliva	1.5	Mucus	6
Urine	5.5	Aqueous Humor	11
Bile	3.1	Vitreous	14

ORIGIN AND DISCHARGE.—It is introduced with the different kinds of animal and vegetable food and fluids, and as a condiment. Being soluble, it is taken up by absorption from the intestines, and is deposited in different parts of the body. About $\frac{4}{5}$ is discharged from the body in the urine, fæces, perspiration and mucus, the remaining $\frac{1}{5}$ being supposed to be changed in the body by double-decomposition

with potassium phosphate, resulting in the formation of sodium phosphate and potassium chloride. It is also supposed to furnish the sodium to all the salts of that metal.

FUNCTION.—It regulates, to a certain extent, the process of osmosis, for we know that a solution of sodium chloride permeates an animal membrane much less readily than pure water. In the blood it holds in solution the albumen and earthy phosphates, and preserves the integrity of the blood corpuscles. As an article of diet, it stimulates the secretion of saliva and gastric juce, and aids in digestion. The importance of sodium chloride in this respect has been demonstrated by Boussingault in the fattening of animals. A small herd of animals were experimented upon, all of the same age, size and vigor. They were divided into two lots and all supplied with an abundance of nutritious food. One of these lots was deprived of this salt (except what was contained in the food), while the other received about 500 grains per day. No difference was observable for four or five months; from that time to the end of the year a marked difference was noticed. Those animals which received the sodium chloride had a fine, sleek, healthy aspect, contrasting strongly with the listless and inanimate appearance of the others. The animals of the forest, as the buffalo and deer have their "salt-licks" to which they resort from time, to time.

POTASSIUM CHLORIDE, KCl.—This substance is found in the muscles, liver, milk, chyle, blood, gastric juice, bile, saliva, mucus and urine, associated with sodium chloride. It is quite soluble in the fluids, and is more abundant in muscle and milk, than sodium chloride, less so in blood, gastric juice and perspiration.

ORIGIN AND DISCHARGE.—It is introduced with the food and is also supposed to be formed in the interior of the body by double-decomposition as previously stated. Potassium chloride is discharged in the urine, mucus and perspiration.

FUNCTION.—Its function is probably identical with sodium chloride.

Lime Phosphate, $Ca_3P_4O_8$. — Lime phosphate is found in all the solids and fluids of the body, but is more abundant in the solids, and increases as age advances. It exists in a solid state, as in the teeth, bones; and also in a fluid state, as in the blood. It is insoluble in water; but is held in solution in the fluids of the body by albumen and the alkaline chlorides, In the urine, is is held in solution by the acid sodium biphosphate, so that when the urine is rendered alkaline the phosphates form a turbid precipitate. In bone or cartilage, it does not exist as a granular powder, but is intimately united with the animal matter, and may be dissolved out by maceration in dilute muriatic acid, leaving behind the animal substance. When a long bone like the fibula is immersed in this way for some time, it loses its brittleness, and may be bent double, or tied in a knot, without breaking. If immersed in a solution of lime carbonate, its rigidity may be again restored to a certain extent.

QUANTITY OF LIME PHOSPHATE IN 1,000 PARTS.

Solids.	Enamel	885.	*Fluids.*	Urine	.7
	Dentine	643.		Milk	2.7
	Bone	550.		Gastric Juice	.4
	Cartilage	40.		Blood	.3
	Muscle	2.5		Saliva	.6

Origin and Discharge.—This substance is derived exclusively from exterior sources. It is introduced with the food, in nearly all forms of which it is found, and is eliminated by the urine, perspiration, and mucus; most by the urine, a small quantity only by the fæces and perspiration.

Function.—Its use is to give consistence and strength to parts; for example, in the enamel of the teeth, which is the hardest tissue in the body, it is most abundant, and in dentine more abundant than in bone. Its presence in milk is subservient to the growth and development of bone in the young of the mammalia.

Lime Carbonate, $CaCO_3$.—This substance exists in the

bones, teeth, cartilage, blood, sebaceous matter, internal ear (otoliths), and in the urine. In bone it is not so abundant as lime phosphate, the proportion being about 113 parts in 1000. It is held in solution in the blood and urine by the free carbonic acid and alkaline chlorides.

ORIGIN AND DISCHARGE.—It is introduced into our bodies with the food and drink. Spring water contains a variable amount, held in solution by the free carbonic acid which the water contains.

FUNCTION.—Its function is analogous to that of lime phosphate.

SODIUM AND POTASSIUM CARBONATES, Na_2CO_3, K_2CO_3.—Sodium and potassium carbonates are found in the bones, blood, lymph, saliva, and urine. They give to the blood its alkaline reaction. Claude Bernard has shown that the alkalescency of the blood is necessary to life; for if a mineral acid be injected into the blood of a living animal, so dilute as not to coagulate the albumen, death takes place before its alkaline reaction has been completely neutralized.

ORIGIN AND DISCHARGE.—They are introduced in small quantities in the food, but are principally formed within the body by decomposition of other salts, malates, tartrates, and citrates of the alkaline bases. These salts when introduced into the body in the food are decomposed. Their organic acid is destroyed and replaced by carbonic acid, forming sodium and potassium carbonates. They are discharged in the urine and mucus.

FUNCTION.—Their function is to maintain the fluidity of the fibrin and albumen, to give alkalescency to the blood and secretions and to assist in preserving the form and consistence of the blood corpuscles.

SODIUM AND POTASSIUM PHOSPHATES, Na_2HPO_4, K_2HPO_4,—These substances exist in all the solids and fluids of the body. They are soluble in water, possess an alkaline reaction and are known as the *alkaline phosphates*. These, together

with the alkaline carbonates are essential to the maintenance of the alkaline character of the fluids of the body, all of which possess an alkaline reaction except the following, which are acid;

1 Gastric juice. 3 Urine.
2 Perspiration. 4 Mucus of the Vagina.

The fluids of the carnivorous animals contain a preponderance of the alkaline phosphates; the herbivorous a preponderance of the carbonates. The former is owing to the phosphates found in the animal tissues upon which the carnivora feed.

ORIGIN AND DISCHARGE.—They are introduced in the food, both animal and vegetable, and are also partly formed in the body by the oxidation of phosphorus and its union with the alkaline bases. They are discharged in the urine, perspiration and mucus.

FUNCTION.—Together with the alkaline carbonates they give to the blood and secretions their alkaline reaction. This condition of the blood increases its power of dissolving carbonic acid, and also favours the elimination of the latter by the lungs. A small proportion of sodium phosphate added to water, enables it to dissolve twice the usual quantity of carbonic acid, and the other alkaline salts have a similar action.

The acid sodium biphosphate, is found in urine, and gives to that fluid its acid reaction. It is formed from the sodium phosphate by the action of uric acid which combines with a portion of the sodium.

SODIUM AND POTASSIUM SULPHATES, Na_2SO_4, K_2PO_4— These exist in small quantity,—in some fluids only a trace, as in milk, saliva, &c. They are found in blood, lymph, milk, saliva, mucus, perspiration, urine and fæces. They are more abundant in the urine, than in any other fluid, being a little more than half as much as of the phosphates. They are introduced by the food and drink. A certain amount is also formed in the body in a similar manner to the phosphates, by oxidation of sulphur and its subsequent union with the alkaline bases.

MAGNESIUM PHOSPHATE AND CARBONATE, $MgHPO_4$, $MgCO_3$.—These salts are found in small quantities in nearly all the solids and fluids of the body. Associated with lime phosphate, they are known as the *earthy phosphates,* They are introduced in the food. They are dissolved in the fluids by the alkaline chlorides and phosphates, and in the urine by the sodium biphosphate The salts of magnesium are more abundant in muscles and brain, than the salts of lime. They are eliminated principally by the urine and fæces.

The proximate principles of the first class exist in the animal tissues in the same form in which they occur in the inorganic world. Lime carbonate in the bones is the same as that which is found in limestone rock ; and sodium chloride is similar to that which is found in solution in sea water.

GASES.—Oxygen, nitrogen, hydrogen, carbonic acid, carburetted hydrogen and sulphuretted hydrogen, exist in a gaseous state, and also in solution in some of the fluids of the body.

Oxygen is necessary to the respiratory process. It changes the shape of the blood corpuscles rendering them biconcave, and gives to the arterial blood its bright-red colour. Arterial blood contains about 10 to $12\frac{1}{2}$ per cent of oxygen. Nitrogen exists in very small quantity in the blood and lungs. It is also found in the intestines. Carburetted and sulphuretted hydrogen, also pure hydrogen, are found in the alimentary canal, and in small quantities occasionally in expired air. Carbonic acid is an excretion given off principally by the lungs. From 20 to 25 per cent. is found in venous blood.

PROXIMATE PRINCIPLES OF THE SECOND CLASS.

The substances of this class are all of organic origin, and exist both in vegetables and animals. They consist of carbon, hydrogen and oxygen only, and are therefore non-nitro-

genous. There are two divisions, the *carbo-hydrates* and *fatty* matters. In the former the hydrogen and oxygen are in the proportion to form water, and in the latter the carbon and hydrogen are in much larger quantity than the oxygen.

STARCH, $C_6H_{10}O_5$.—This substance, though not crystallizable, is so closely allied to the others in its general properties, and so easily converted into sugar, which *is* crystallizable, that it is naturally included in the proximate principles of the second class. It is not amorphous, but possesses a distinct granular form. It is found in nearly all the flowering plants, and is the principal ingredient in sago, tapioca, arrowroot, &c.

QUANTITY OF STARCH IN 100 PARTS.

In Rice	88	Wheat Flour	57
" Maize	67	Iceland Moss	44
" Barley Meal	66	Beans	33
" Rye "	64	Peas	37
" Oat "	60	Potatoes	20

PHYSICAL APPEARANCE OF STARCH.—It is a white powder, consisting of solid granules, which vary in shape, size, and physical appearance, in different vegetables. It produces a crackling sensation when rubbed between the fingers. Each starch granule consists of two substances mingled together, *granulose* and *cellulose*. The former, which is more abundant, is soluble in boiling water, the latter is insoluble. The starch granule of potato varies from $\frac{1}{10000}$ to $\frac{1}{400}$ of an inch (2.5 to 62.5 mmm.) in diameter, is pear-shaped in its outline, and marked by concentric rings surrounding a minute pore, called the *hilum*, which is situated near the small extremity of the granule (Fig. 1.)

The granules of arrowroot are oval in shape, small, and more uniform, and vary from $\frac{1}{2000}$ to $\frac{1}{500}$ of an inch (12.5 to 50 mmm.) in diameter (Fig.3). The hilum is in the shape of a circular pore or transverse slit. The starch grains of wheat vary from $\frac{1}{10000}$ to $\frac{1}{700}$ of an inch (2.5 to 35.5 mmm.) in diameter, nearly circular in form, with a round or transverse

hilum, but without any distinct laminar appearance (Fig. 2). The granules of Indian corn are the same size as the preceding; they are irregular in shape, and present a crucial, (Y) or (T) shaped pore (Fig. 4). The granules of rice are very small, uniform in size, polygonal in outline, and present a granular appearance (Fig. 5).

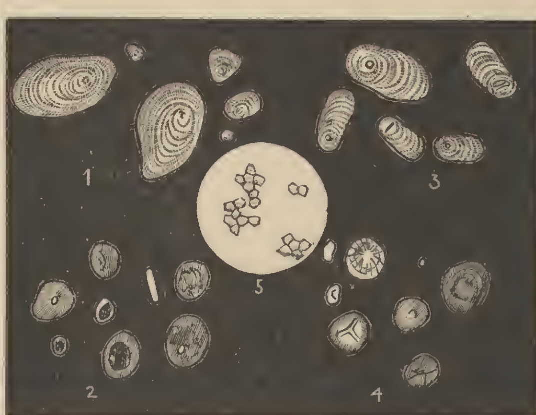
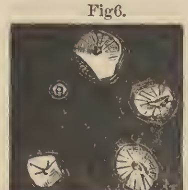


Fig. 1 Starch granules of potato. (2). Starch granules of wheat. (3). Starch granules of arrowroot. (4). Starch granules of Indian corn. (5). Starch granules of rice.

ORIGIN AND PROPERTIES.—It is found in most vegetable substances used as food, and in that way is introduced into the body. It is also found in the animal body in the lateral ventricles of the brain, fornix, and septum lucidum. It was first observed by Purkinje, and afterwards by Kolliker and Virchow. The granules are called corpora amylacea, and vary in size from $\frac{1}{4700}$ to $\frac{1}{1100}$ of an inch (5.5 to 22.5 mmm.) in diameter. They are transparent, softer than in vegetable starch, irregularly rounded, and present a faint laminar arrangement, having a circular pore near the centre, with lines radiating from it—star-shaped.

Fig6.



Corpora Amylacea.

Starch is insoluble in cold water, but the granules swell out, become gelatinous, and are readily dissolved in boiling

water. It is then said to be hydrated. This is simply a mechanical change. Starch may be converted into *dextrine*, by torrefaction—a dry heat of 210° (400 F.) This substance which is of a gummy nature, is so named because in solution it rotates the plane of a polarized ray of light towards the right.

Starch may also be converted into *sugar*, in three different ways.

Firstly, by boiling in dilute nitric, muriatic, or sulphuric acid for 36 or 40 hours. The starch is first converted into dextrine and then into sugar, and at the same time loses its property of responding to the iodine test.

Secondly, by contact with an animal or vegetable substance, at a temperature of 37.5° (100°F.) Boiled starch mixed with saliva is converted into sugar in a few minutes.

Thirdly, by the process of nutrition and digestion in animals and vegetables. The starch found in seeds and roots is converted into sugar by the presence of diastase, and thus rendered soluble before it can be taken up to nourish the plant during its growth.

FUNCTION.—Its office in the animal economy is to form sugar. Starch is converted into sugar during digestion by the action of the pancreatic and intestinal juices. It is necessary for the process of development and nutrition at all periods of life. It is the source of sugar in the vegetables.

TEST.—In whatever state it exists, its presence may be detected by its reaction with free iodine, giving a blue color. Ozone test-paper is prepared on this principle. White paper is first saturated in a solution of starch, and then in potassium iodide. When exposed to an atmosphere containing ozone, the latter oxidizes the potassium and liberates the iodine which reacts upon the starch, and stains the paper blue.

GLYCOGEN, $C_6H_{10}O_5$—This is the name given to an amylaceous substance found in animal bodies. It exists in the

liver of all vertebrate animals, also in the muscles and integument at an early period of development. It gives a violet-red color with iodine, instead of blue. It is soluble in water and is easily changed into sugar or glucose, by boiling with a dilute acid, or by contact with an animal substance. It is the source of sugar formed in animals, as starch is in vegetables.

SUGARS.—These substances are soluble in water, crystallize on evaporation, and are converted into alcohol and carbonic acid in the process of fermentation. The ordinary varieties of sugar are: *glucose* or grape sugar, *saccharose* or cane sugar, and *lactose* or milk sugar. Saccharose is more soluble than any other variety, and is therefore sweeter. Glucose crystallizes with difficulty, but ferments readily; while cane and milk sugar ferment with difficulty. Sugar is necessary in the process of nutrition at all periods of life, and is also supposed to assist in maintaining the animal heat of the body. It is never discharged from the body in health (except in the female during lactation); but in certain diseased conditions of the system, it is rapidly produced in the liver, in the form of glucose and is discharged in the urine, constituting *diabetes mellitus.*

TABLE OF QUANTITY OF SUGAR IN 100 PARTS.

In Figs	62.50	Wheat Flour	2.33
" Cherries	18.52	Rye do	3.46
" Peaches	11.61	Ind'n Corn do	3.71
" Tamarinds	12.50	Peas	2.00
" Pears	11.52	Cow's Milk	5.20
" Beets	8.00	Asses do	6.08
" Barley	3.04	Human do	6.50

It is an important article of diet. It is introduced with the milk in the food of the child. In the adult it is introduced partly in the food as sugar; but mostly in the form of starch, which is converted into glucose during digestion by the action of the pancreatic and intestinal juices.

GLUCOSE, $C_6H_{12}O_6$—This variety is named grape sugar because it exists in large quantity in ripe grapes and

sweet fruits. Glucose is found in the interior of the body, in the liver, blood, lymph, chyle, and in the placenta of the fœtus during the first three months of fœtal life. It is found in the portal and hepatic veins, but disappears from the blood in its passage through the lungs, being probably converted into lactic acid. It is readily soluble in water, and has a moderately sweet taste. It may be formed from starch by boiling with a dilute acid, by contact with animal substances at a temperature of 37.50° (100 F), or by the action of a nitrogenous substance in a state of decay, as vegetable diastase.

TESTS.—TROMMER'S TEST.—To the suspected liquid add one or two drops of a solution of copper sulphate; render it alkaline by the addition of a solution of caustic potassa. The whole solution then assumes a blue color. Then boil it for a few minutes, and if sugar be present, copper suboxide is thrown down as a yellowish or reddish-brown precipitate. If no sugar be present, the liquid remains blue. The principle of this test depends upon the power sugar has in reducing the copper protoxide to the suboxide, in the presence of an alkali, which is added to liberate and neutralize the sulphuric acid. This test is not applicable to cane or milk sugar; but by boiling them in dilute sulphuric acid they are converted into glucose, which responds readily. Liver and milk sugar act promptly with Trommer's test. Care should be taken that only a small quantity of copper sulphate be added, as there might not be sufficient sugar in the solution to reduce it.

Organic substances, as albuminose, interfere with this test. This substance may be precipitated by alcohol, and removed. Albuminose will be described among the proximate principles of the 3rd class.

"FEHLING'S LIQUOR" TEST.—The principle is the same as in Trommer's test, but it is a much more delicate test. The solution is prepared according to the following formula:

Copper Sulphate, crystallized . . .	40 grammes	=(617 grains)
Potassium Tartrate, neutral	160 "	=(2468 ")
Sodium hydrate in solution sp. gr. 1.12	650 "	=(10029 ")

The first two are dissolved in water, mixed with the alkaline solution and water added to make 1154·4 cubic centimetres =(2 pints.)

Add to the suspected mixture enough of the solution to give it a blue tinge, and boil. If sugar be present, the copper suboxide is thrown down, as in Trommer's test. A single drop of this liquid will detect $\frac{1}{15}$ of a milligramme =($\frac{1}{1000}$ of a grain) of glucose. It should be kept excluded from light and air, otherwise it will become changed and unfit for use.

FERMENTATION TEST.—Add a few drops of fresh yeast to the saccharine liquid, and keep it at a temperature of about 25° (77°F.), in this way the sugar is converted into alcohol (C_2H_6O), and carbonic acid (CO_2); the latter should be collected in a vessel and examined. Every cubic inch of carbonic acid is about equal to one grain of sugar. The presence of carbonic acid may be proved by introducing into the vessel a lighted taper, which will be immediately extinguished; or by agitating with lime water, which will be rendered turbid by the formation of insoluble lime carbonate. The fermentation of glucose is due to the vegetation of a microscopic fungus, *saccharomyces* or torula *cerevisiæ*. The fungus is entirely cellular, the cells being rounded or oval, with one or two nuclei and about $\frac{1}{2500}$ of an inch, (10 mmm.) in diameter. They multiply by a process of budding, and occasionally two or three of them may be seen adhering together. They may be observed on the surface of diabetic urine, which has stood for some time. They break up after a time and fall to the bottom of the vessel, in minute oval spores.

MOORE'S TEST, *or, the Potash Test.*—A little caustic potash in solution is added to the suspected liquid, and boiled in a test tube. If sugar be present it acquires a brownish color. This is not a very reliable test.

SACCHAROSE, *or cane sugar* $C_{12}H_{22}O_{11}$.—Saccharose is very soluble, readily crystallized, and the sweetest of all the

sugars. It exists in the sugar cane, maple, beet, parsnips, carrots, turnips etc., and is chiefly used for culinary purposes. It is formed from glucose in the process of vegetation. It will thus be seen that starch and sugar are closely allied to each other in all their relations—and are mutually convertible, starch being the solid formation, and sugar the active liquid one. Cane sugar will not respond to Trommer's test, nor ferment until it has been transformed into glucose by boiling it for a few seconds with a dilute mineral acid, or by adding yeast to it.

Lactose, *or sugar of milk*, $C_{12}H_{24}O_{12}$.—This form of sugar is found only in milk, and is a constant ingredient. It is less soluble than the other forms, and therefore not so sweet. It undergoes alcoholic fermentation slowly and incompletely, and when it takes place in milk a part of the sugar is transformed into lactic acid—known as the lactic acid fermentation. It responds readily to Trommer's and Fehling's tests. It is supposed to be formed from glucose by catalysis in the mammary gland.

Oils and Fats.—These substances are found in both animal and vegetable tissues. The three principal varieties of fat which exist in the animal economy are: Oleine—$C_{57}H_{104}O_6$; Margarine or Palmitine—$C_{51}H_{98}O_6$; and Stearine—$C_{57}H_{110}O_6$. By the chemist these bodies are considered as salts, formed by the union of fat acids with the base—glyceryl—thus :—

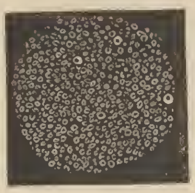
Oleine ..	Oleic Acid ($C_{18}H_{34}O_2$) and Glyceryl (C_3H_5	................Oleate of Glyceryl.
Palmitine	Palmitic Acid ($C_{16}H_{32}O_2$) and Glyceryl (C_3H_5	..........Palmitate of Glyceryl.
Stearine.	Stearic Acid ($C_{18}H_{36}O_2$) and Gylceryl C_3H_5).........	..............Stearate of Glyceryl.

These may be separated from each other by the process of saponification. When oleine, palmitine, or stearine, is boiled in a solution of caustic alkali, it is decomposed into a fat acid, as oleic, palmitic, or stearic, and a sweetish viscid fluid

the hydrate of glyceryl, or glycerine. The acid unites with the alkali and forms soap, and glycerine ($C_3H_53HO.$) is set free. The fat acid may also be separated from the base, glyceryl, by passing steam through fat at a temperature of 300° (572° F.) The human body, when immersed in water for a length of time, becomes changed into a substance called *adipocere*, or saponified fat. This is supposed to be a process of saponification, caused by the union of palmitic, stearic, and oleic acids with ammonia, which is developed during the process of decomposition.

PHYSICAL APPEARANCE AND PROPERTIES OF FAT.—It exists in two forms in the body. First, in the form of large cells or vesicles, varying in diameter from $\frac{1}{800}$ to $\frac{1}{300}$ of an inch (31 to 83 mmm.), as in adipose tissue, (Fig. 9.) Secondly, in the form of oil globules, varying from $\frac{1}{20000}$ to $\frac{1}{4000}$ of an inch, (1.2 to 6 mmm.) as in the chyle, in which it is said to be emulsified, (Fig 7.) This is a mechanical subdivision of the fat

Fig. 7.



Fat globules of chyle.

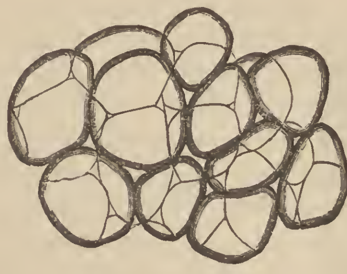
Fig. 8.

Fat globules of cow's milk.

cells, and is the only form in which it can be absorbed. Fats may be emulsified by means of alkalies, serum of blood, mucilage, or white of egg. The fat cell is characterized by a dark border surrounding a bright centre; usually no nucleus is seen, but it may occasionally be found attached to the cell wall. It is generally rounded in shape, but is found irregular in outline, depending on pressure. The small globules appear as minutely dark granules, so as to give the fluid in which they float an opalescent appearance. In cow's milk, the oil globules are $\frac{1}{4000}$ of an inch (6.25 mmm.) in diameter, have a pasty consistence, due to the palmitine they contain;

and when churned, are converted into butter, from their tendency to cohere. Oleine, palmitine, and stearine, are always found mingled together in the body; but they are never associated with any of the other proximate principles of the body, as water, sugar, &c. The only exception is the nerve tissue, in which they are combined with albumen, and

Fig. 9.



Fat cells of adipose tissue.

also in the bile dissolved in the salts. They are united with phosphorus, constituting the phosphorized fats of nerve tissue. This union is supposed to take place in the lungs under the influence of oxygen. In the living body, the fats are fluid, or nearly so, being held in solution by oleine; but after death, they assume the solid condition. Stearine and palmitine are crystallizable, and sometimes present a very beautiful appearance. The crystals are needle-shaped, and are deposited in a radiated form, but sometimes curved and branching. Stearine predominates in hard, palmitine in soft, and oleine in liquid fats. The melting point of stearine is 60°, (140° F.), palmitine 46°, (115° F.), and oleine 38°, 100° F. They are insoluble in water, but are soluble in ether and hot alcohol.

TABLE OF QUANTITY OF FAT IN 100 PARTS.

Linseed	22.00	Cow's milk	3.70
Eggs	7.00	Human "	3.55
Liver of calf	5.58	Beans	2.50
Beef, average	5.19	Wheat	2.10
Salmon	4.85	Potatoes	.11
Goat's milk	3.82	Indian Corn	.9

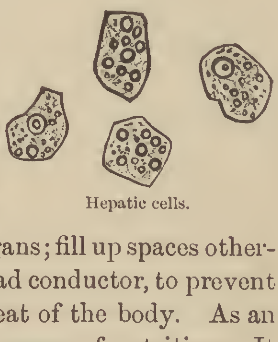
ORIGIN AND FUNCTION.—It is found in all parts of the body except in the compact tissue of the bones, teeth, tendons, beneath mucous membranes, in the cutis, between the rectum and bladder, beneath the epicranial aponeurosis, in the ligaments, scrotum and eyelids. It is introduced in the food, and is emulsified by the pancreatic juice during digestion and previous to absorption. It is also formed in the interior of the body. This has been proved by experiments on geese, the result of which showed more fat in the body than could be accounted for by that which existed in the food. Another proof is, that it has been found in the form of globules in the interior of the costal, laryngeal, and tracheal cartilage cells, and also in the muscular fibre cell of the uterus during involution (Fig. 10,) It also exists in the form of globules in the hepatic cells (Fig. 11,) sebaceous glands, corpus luteum and uriniferous tubes of the carnivora: In the marrow of bones, it exists both in the form of oil globules, and fat cells forming adipose tissue. In some parts, it is formed from blastema supplied by the blood vessels, as in adipose tissue; in others it is formed as the result of a retrograde metamorphosis, as in the muscular fibre cell of the uterus.

Fig. 10.

Uterine muscular fibre cells, two weeks after parturition

It accumulates in excess in certain diseased conditions, as in fatty degeneration of the heart, liver, kidney. Its function in the form of adipose tissue, is to give rotundity to the body; form a nidus for delicate organs; fill up spaces otherwise unoccupied, and from being a bad conductor, to prevent the too rapid escape of the animal heat of the body. As an article of diet, it is necessary in the process of nutrition. It

Fig. 11.



Hepatic cells.

supplies animal heat, and is a store of food in case of emergency, as in the hybernating animals. Certain kinds of food favor the formation of fat; for example, negroes employed in making sugar grow fat from the quantity of sugar they eat. It is said to accumulate more rapidly when the animal is fattened in a darkened room. Fat is absorbed from the body in some diseases, and its place supplied with serum, as in consumption. It is discharged by the sebaceous glands of the skin, and in the milk of the female during lactation.

CHOLESTERINE, $C_{26}H_{44}O$.—This substance may be described among the oils and fats. It is found in bile, blood, liver, nervous tissue, crystalline lens, and meconium. It differs from ordinary fat in the fact that it is not capable of saponification, is volatile at a high temperature and rotates a ray of polarized light to the left. It crystallizes in thin transparent rhomboidal plates, is insoluble in water, but soluble in ether, chloroform, hot alcohol, and volatile and fatty acids. When treated with sulphuric acid and chloroform it produces a peculiar red color, which soon changes on exposure to air to violet, blue, green and finally fades away. It melts at 145° (293°F) and distils at 360°. (680° F).

PROXIMATE PRINCIPLES OF THE THIRD CLASS.

The substances belonging to this class are very important as they have an intimate connection with the active phenomena of living bodies. They are not crystallizable, and are not definite in their chemical composition; that is, they do not always contain the same proportions of oxygen, hydrogen, carbon, and nitrogen, but the relative quantities of these elements may vary, within certain limits, in different individuals, and in the same individual at different times, without changing in any material degree the peculiar properties of the substance which they form. This is characteristic of organic substances. They all closely resemble albumen, hence called "albuminoid substances". Their reaction is neutral. They were regarded by Mulder as com-

pounds of a theoretical radical, which he called protein. This gave them the name of "protein compounds". The albuminoid substances are all *hygroscopic.* In some parts of the body they are fluid, and in others semi-solid, or solid, depending upon the amount of water which they contain. When subjected to evaporation they lose water, and may be reduced to a solid state. Advantage is taken of this fact in the preservation of eggs,, milk etc., by evaporating at a low temperature and hermetically sealing in cans. When water is added, they again absorb it, and return nearly to their original condition.

They are all capable of being coagulated. Fibrin coagulates spontaneously, when removed from the vessels; albumen, on the application of a temperature of 71° (160°F.); and casein on the addition of an acid. An organic substance, once coagulated, cannot be restored to its original condition. It may be dissolved by certain re-agents, as *e. g.*, the caustic alkalies; but in this it only suffers a still further alteration; nevertheless it is necessary to resort to coagulation to remove an organic substance from the other proximate principles with which it is associated. Fibrin is obtained by switching freshly-drawn blood with a bundle of twigs. Thus obtained it is an unnatural condition, having lost its original character of fluidity.

These organic substances, when the vital force is removed, are liable to putrefaction. This process is peculiar to organic nitrogenized substances, and distinguishes them from all other proximate principles. When in a state of putrefaction, they are capable of inducing in certain other substances a process of fermentation, as for example, the decaying organic matters of the grape give rise to fermentation of the sugar, converting it into alcohol and carbonic acid. The putrescent body is called a ferment, and acts by catalysis, or by its mere presence, having nothing to do chemically with the process. The conditions necessary to putrefaction are, the presence of oxygen, heat, and moisture. If oxygen

be excluded by boiling, and the substance be placed in hermetically sealed vessels, in an atmosphere of carbonic acid, or nitrogen, putrefaction will not take place. The same is the case if the substance be dried, or if the temperature be kept near the freezing or boiling points respectively.

During the process of putrefaction, there will be observed swarms of minute microscopic organisms floating about in the fluid, called bacteria and micrococci, (Fig. 12); the former are so named from their rod-like form, and consist of two small cells placed end to end; the latter are so called because of their minuteness, and appear like small specks. Both are in a state of incessant and rapid motion. Bacteria are increased by spontaneous subdivision of the cell into two, each of them again subdividing, and so on. The variety found in putrefying infusions is known as the *bacterium termo*. They are believed by some to be vegetable organisms, which are spontaneously developed in the albuminoid substance, and cause putrefaction to take place. By others, they are supposed to be derived from germs floating in the air, and which become developed in putrefying substances.

Fig. 12.

A.—Bacteria. B.—Micrococci.

Albuminous matters are found in most substances used as food, the proportion according to Payen being as follows:

QUANTITY OF ALBUMINOUS MATTER IN 100 PARTS.

Beans	24.40	Oysters	14.00
Mackerel	24.30	Salmon	13.50
Peas	23.80	Indian corn	12.50
Beefsteak	19.50	Eggs	12.30
Wheat	18.00	Rice	7.50
Oats	14.30	Potatoes	2.50

ALBUMEN.—This substance is named albumen from "Albus," white, on account of its appearance when coagulated. It exists both in the fluid and solid state in the body—fluid in the blood, lymph, chyle, cerebro-spinal fluid, serous and

synovial fluids, and milk,—solid in the brain, spinal cord and nerves. It is also found in mucous membranes, muscular tissue, and in the aqueous and vitreous humors of the eye. It exists in the white of egg, and can be easily coagulated or made to assume a solid form.

Composition and Properties.—The average chemical composition of the albuminous substances is as follows:—(Fremy,)

Carbon	52.0
Hydrogen	6.9
Nitrogen	15.6
Oxygen	24.0
Sulphur	1.5

Albumen does not coagulate spontaneously, but may be coagulated by any of the following re-agents, viz., heat at 71° (160°F.), alcohol, mineral acids, as nitric, sulphuric, etc., tannic acid, potassium ferrocyanide in an acid solution, and the metallic salts. It is very readily coagulated by bichloride of mercury, and hence it is used in cases of poisoning from that salt. It unites with it to form the so-called albuminate of mercury. The white of one egg is sufficient to neutralize four grains of the bichloride. Albumen coagulates at the negative pole of the battery, if not too strong a current, and at both poles when a strong battery is used. It is not coagulated by the vegetable acids, except tannic acid. The fresh juices of vegetables contain a substance coagulated by heat, called *vegetable albumen.*

When albumen is evaporated at a temperature of 49° (102° F.) it becomes solid and brittle, but otherwise unchanged, and may be re-dissolved in water. When coagulated by heat or the mineral acids, &c., it cannot be re-dissolved or made to resume its original condition. It is held in solution in the body by sodium chloride, sodium and potassium carbonates and phosphates, which give it an alkaline reaction. It exists in a neutral state in diseased blood, the egg, renal, splenic and hepatic veins. It parts with some of the soda in passing through the spleen, kidney, and liver.

Origin and Function.—It is derived from the albuminoid elements of the food, by a catalytic process during digestion. It is the nutrient element of the blood, and the pabulum of all the tissues. When it is withheld from the food, or withdrawn from the body in disease, as in albuminuria, the nervous and muscular tissues suffer most. It is converted into fibrin through the agency of the blood-cells and oxygen; this is probably a chemico-vital process. Albumen is never discharged from the body in health. In a diseased state of the kidney it is found in the urine, as in Bright's disease, also in scarlatina, diphtheria, and in the cold stage of cholera.

Tests.—These depend on its property of coagulation.

First. Heat.—When a solution containing albumen is heated in a test tube to 75° (167°F), a precipitate, more or less abundant, is formed. If, however, the liquid be alkaline the albumen will not coagulate; hence an acid, as acetic acid, should be used to neutralize it. The earthy phosphates of the urine, when in excess, are thrown down by heat; but these may be distinguished from albumen by the addition of a few drops of hydrochloric acid, which clears up the phosphates, but has no action on the albumen.

Secondly. Nitric Acid.—When this is added to a solution containing albumen, a precipitate is instantly formed. When the urates are abundant in the urine, nitric acid causes a deposition of uric acid, but this may be re-dissolved by an excess of nitric acid.

Albuminose or Peptone.—This is a colorless liquid found in the chyle and blood. It differs from albumen from the fact that it is not coagulated by heat, nitric acid, or potassium ferrocyanide. It is coagulated by alcohol in excess, and the metallic salts. When in solution in the gastric juice, it interferes with Trommer's test for grape sugar. It is found in the stomach and intestines, only during digestion. When Trommer's test is applied to a saccharine liquid containing albuminose, a purple color is produced on the ad-

dition of the re-agents, and when boiled, the color changes from red to yellow, but no copper suboxide is thrown down. This test may be made to apply, by evaporating the solution to dryness, and making an alcoholic extract, then a watery solution of the sugar contained in the extract will respond as usual. It also interferes with the mutual reaction of starch and iodine, no blue color being produced.

Origin and Function.—It is formed from the organic nitrogenized elements of the food, as fibrin, albumen, and casein, etc., by the action of the gastric juice during the process of digestion. It is absorbed in this state, and is converted into albumen in the blood. It is much more easily absorbed than albumen, on account of its superior osmotic properties. It is the soluble principle of fibrin, albumen, casein, &c.

Fibrin.—Fibrin exists in the blood, lymph, and chyle as found in the lacteals. When blood is removed from the vessels, it soon separates into a solid portion, or clot, and a fluid portion, or serum. The clot consists of coagulated

Fig. 13.

Coagulated fibrin containing white blood corpuscles.

fibrin, containing red and white corpuscles entangled in its meshes. When inflammation is present, the red corpuscles have a tendency to cohere, and sink to the bottom of the vessel, hence the fibrin is more abundant at the top, and from the

peculiar color it presents, is called the "buffy coat." Fibrin is difficult to obtain free from corpuscles. It may be obtained nearly pure, by switching freshly-drawn blood with a bundle of twigs. It coagulates on the twigs, and may be freed from impurities by washing. It is first washed with water, to remove the salts, then with alcohol, to remove the pigment, and ether, to remove fatty matters. Another mode is to filter frogs' blood, the corpuscles of which, being large, are kept back; but the liquor sanguinis passes through, and the fibrin coagulates, and may be washed as above. A little thin syrup, or a weak solution of an alkali, should be added to retard coagulation during filtration. It is sometimes found in a tolerably pure state, in the cavities of the heart and large arteries after death. It is also found arranged in laminæ, in the sacs of aneurisms. It is regarded by some as formed by the union of two substances in the blood, fibrinogen and fibrinoplastin, and by others as resulting from the decomposition of a substance called plasmine.

PHYSICAL APPEARANCE AND PROPERTIES.—Fibrin is a greyish-white, tough, elastic and stringy substance, composed of microscopic fibrils. It possesses the property of "spontaneous coagulation," or fibrillation. It is insoluble in water, alcohol, and ether, but is soluble in the alkalies. Three-fourths of its weight is water. When treated with acetic acid, it swells out, becomes soft and gelatinous, and slightly soluble in water. It may be dissolved in cold concentrated hydrochloric acid, and after a time the solution acquires a blue color. When dissolved in the potash salts, it resembles albumen in its properties and reactions. When boiled in water, it forms binoxide and teroxide of protein. When boiled in hydrochloric acid, it yields "leucine" and "tyrosine." It is held in solution in the blood by the alkaline chlorides and carbonates.

COAGULATION.—The coagulation of fibrin is a process of fibrillation. When the process of coagulation is viewed with a microscope, a granular appearance is first noticed; some of

the granules become star-shaped by the addition of other granules, the arms being directed towards the corpuscles which are ultimately included in the meshes. When fully organized it is distinctly fibrous in structure. Coagulation of the fibrin takes place more slowly in the absence of the corpuscles, as in filtered blood. Certain vegetable substances as wheat flour, contain an albuminous matter very similar to fibrin, called gluten, or *vegetable fibrin.*

Origin and Function.—Fibrin is formed from albumen, by the influence of the corpuscles and oxygen; in other words, it is albumen in a higher state of organization. It gives to the blood its property of coagulation, and it is through this property that "natural hæmostasis" is effected. It gives to the blood its viscidity, and prevents it from exuding through the coats of the vessels. It was formerly supposed to be the material which was thrown out, and subsequently became organized, in the repair of wounds, and in inflammation, under the name of "coagulable lymph" Lymph is now generally believed to be the product of the white corpuscles, which have passed through the coats of the vessels by virtue of their amœboid movement, supplemented by the proliferation of connective tissue elements in the wounded or inflamed parts.

Fibrin was by some considered as effete matter, formed from the worn out elements of the blood and tissues, and the arguments adduced in favour of that view were, that it was increased in bleeding and starvation; that there was none found in the renal veins, having been discharged by the kidneys; that there was very little in the blood of the fœtus; none in the egg; none in the chyle until it entered the lacteals, and then only as the result of the additions made to it from the blood or lymph.

Casein.—This is an albuminous principle found only in milk. It is held in solution by the alkaline carbonates, and when any of the organic or mineral acids, or magnesium sulphate is added, the alkali is neutralized, and coagulation

of the casein follows. It is also coagulated by a solution of *rennet,* the abomasus, or fourth stomach, of the young of ruminants. The pepsine contained in the stomach has the power of converting the sugar of milk into lactic acid, which neutralizes the alkali, and causes a precipitate of casein. This is a catalytic process. Casein is also coagulated during a thunder storm ; a substance called ozone is developed in the atmosphere, which acts on the casein and decomposes it. The decaying casein acts as a ferment, and converts the sugar of milk into lactic acid, which precipitates the casein. Casein differs from albumen ; it is not coagulated by heat, and is precipitated by organic acids. The precipitate of casein may be re-dissolved by a solution of caustic alkali. It is insoluble in water and alcohol. An albuminous substance called *vegetable casein* is found in beans, peas, &c.

Origin and Function.—It is formed from the albumen of the blood by a catalytic process in the mammary gland. It has been found in the blood of puerperal women. Casein may be obtained in a nearly pure state, by precipitating it with acetic acid, and then washing the precipitate with alcohol and water. It is the chief aliment of the young of the mammalia, and the substance from which all the tissues are formed.

Globuline.—This is a semi-solid substance found in the crystalline lens, in the blood globules, and in the structure of cells generally. It is coagulated by heat, alcohol, and the mineral acids. It is soluble in water, but not in the liquor sanguinis of the blood. The coagulum of globuline is partly soluble in hot alcohol ; this distinguishes it from albumen. Acetic acid causes it to swell out and become transparent. The globuline of the crystalline lens is called by some "*Crystalline.*" It is more easily coagulated than globuline.

Pepsine.—This is the organic principle of the gastric juice. It is coagulated by heat and alcohol, and is with

difficulty distinguished from albumen. It exists in the gastric juice in the proportion of fifteen parts per thousand, from which it may be precipitated and extracted by means of alcohol. The solvent power of the gastric juice depends on the presence of pepsine. This will be discussed in the chapter on digestion.

Pancreatine.—This substance exists in the proportion of ninety parts per thousand in pancreatic juice. It is a viscid fluid, coagulable by heat, alcohol, and strong acids. It is coagulated by magnesium sulphate; this distinguishes it from albumen. It has the property of emulsifying oils and fats, and of converting starch into sugar during the process of digestion. It is formed from the albumen of the blood in the pancreas.

Ptyaline is an ingredient in saliva, and gives it the property of converting starch into sugar. It is not coagulated by nitric acid or acidulated potassium ferrocyanide. This distinguishes it from albumen. It is precipatated by alcohol and boiling, and in the latter case loses its power of converting starch into sugar.

Mucosine.—The organic substance of mucus is termed mucosine. In some of its properties it resembles albumen. It is coagulated by alcohol and acids, but not by heat, or the metallic salts. It lubricates the free surface of mucous membranes, and is formed from the blood by the agency of the cells, which line the free surface of the membrane and its follicles.

Musculine or Myosine is a semi-solid substance peculiar to muscular tissue. It is insoluble in water, but is soluble in a mixture of ten parts of water with one of hydrochloric acid, and may be precipitated again by neutralizing with an alkali. It is a most important element of animal food, and is the great source of albumen and fibrin.

Cartilagine is the organic ingredient of cartilage. By prolonged boiling, it is transformed into a substance called

"chondrine." It is precipitated by acids and some of the metallic salts; this distinguishes it from "gelatine."

Collagen.—This substance is peculiar to bones, tendons, ligaments, etc. It constitutes the principal part of the animal matter. By prolonged boiling, it is converted into "gelatine" or "glue," and is then soluble in water.

Elasticine.—This is the organic principle of the yellow elastic tissue. It is not soluble in water, alcohol, ether, or acetic acid, but is dissolved and decomposed in nitric, sulphuric and hydrochloric acids, and these solutions are not precipitated by alkalies.

Keratine.—This is an organic substance, found in the epidermis, nails and hair. It is not affected by boiling in water, alcohol, ether and dilute acids, except by continuous boiling in a Papin's digester at 150° (302°F).

COLORING MATTERS.

The substances of this group give to the tissues and fluids their distinctive coloration. They are all supposed to be crystallizable, and formed from the coloring matter of the blood. The coloring matter may be removed from the fluids of the body by filtering through *animal charcoal*, which has the property of removing coloring matter from any fluid. Animal charcoal will also remove albuminous matter from any fluid containing it. The most abundant and important of the coloring matters is

Hemoglobine.—It is analogous in many respects to chlorophyl in the vegetable kingdom, for while hemoglobine is the agent on the one hand by which oxygen is carried into the system, chlorophyl, on the other, is the agent by which carbonic acid and water are decomposed and oxygen set free in the vegetable. It exists in the blood corpuscles in the proportion of 25 to 30 per cent., and also in muscular tissue. It is soluble in water, dilute alcohol, and alkaline salts, but is insoluble in strong alcohol, ether and oils. It crystallizes out in rhombic or hexagonal plates or prisms,

3

differing in different species, and also in the same species under different circumstances. It is easily decomposed. Its characteristic property is its great power of absorbing oxygen, which it holds in a free state, until it yields it up to the tissues. When charged with oxygen it becomes bright red, and is called *"oxidized" or scarlet hemoglobine;* when deoxidized, it assumes a purple color, and is called "reduced" or *purple hemoglobine.* It contains 4.2 parts iron per thousand, which is essential to the blood. This is not in the form of an oxide, but is combined with carbon, hydrogen, nitrogen, and oxygen of which it is composed. Iron is also found in the coloring matter of the hair, bile and urine. The blood of an ordinary sized man is said to contain 2.8 grammes (43 grs.) of iron. When the red blood corpuscles are broken down from any cause, the hemoglobine is set free, and the walls of the vessels and tissues are stained. This has been mistaken for arteritis. When the hemoglobine is deficient in the blood, as in anemia, etc., it may be restored by the administration of iron.

MELANINE is a brownish-colored substance, found in those parts of the body where pigment exists, as in the choroid coat of the eye, iris, epidermis and hair. It is very abundant in the epidermis of the negro. It is formed from hemoglobine, but contains less iron. The coloring matter is the same in all situations, the different shades being produced by the arrangement of the pigment cells among the fibres and capillaries of the tissue. In some cases it is entirely absent, as in the "*albino*." It is insoluble in water alcohol, ether and dilute acids, but is soluble in caustic potassa.

BILIRUBINE is formed from hemoglobine in the liver, and constitutes the yellowish-red coloring matter of the bile. It is crystallizable, insoluble in water, but soluble in alcohol, ether, chloroform, and alkaline fluids. It responds readily to "Gmelin's bile test,"—nitroso-nitric acid. If a small quantity of nitric acid be dropped into a solution of bilirubine

to which nitrous acid is previously added, a play of colors is produced in order as follows,—green, blue, violet, red, and yellow. Bilirubine, if rendered alkaline, and exposed to the air becomes changed into biliverdine.

BILIVERDINE is the greenish coloring matter of the bile. It is more abundant in animals that feed upon vegetable food. It is insoluble in water, ether and chloroform, but is soluble in dilute alkaline solutions, alcohol, and acetic acid. It is believed to be formed from bilirubine. It is discharged from the body in the fæces. It is often found in gall stones.

UROCHROME OR UROSACINE is a yellowish-red coloring matter peculiar to the urine. It is found, also, in urinary calculi. It is probably the worn-out hemoglobine of the blood, which is being discharged by the kidney. Urosacine and the coloring of bile are both discharged from the body, the one in the urine, and the other in the fæces. It is soluble in water and in ether, but only slightly so in alcohol.

LUTEINE is a yellow coloring matter found in yolks of eggs and the corpus luteum. It is crystallizable, insoluble in water, but soluble in alcohol, ether, chloroform, and oils. It is easily decomposed, and nitric acid added to it gives a blue color.

CRYSTALLIZABLE NITROGENOUS MATTERS.

The substances of this group are crystallizable, and with one or two exceptions are derived from the nitrogenous matters of the body as the result of retrograde changes. They are lecithine, cerebrine, leucine, and the substances found in urine and bile, as urea, creatine, creatinine, urates and hippurates of soda, glycocholate and taurocholate of soda. The latter will be described with urine and bile respectively.

LECITHINE, formerly described as a phosphorized fat is found in blood, (.4 parts per thousand), bile, spermatic fluid, yolk of egg and nerves, also in certain vegetables. It is

soluble in alcohol, ether, chloroform, and oils, and is easily decomposed. Water swells it up into a pasty mass, and gives rise to so-called "myeline forms," an appearance resembling "myeline" or medullary layer of nerve fibre. It contains phosphorus.

CEREBRINE exists only in brain and nerves, and is more abundant in the white than the gray substance. It is a whitish substance, insoluble in water and ether, but is soluble in boiling alcohol and deposits again on cooling. Heated in the air it turns brown and burns readily.

LEUCINE is found in small quantities in the kidneys, spleen, liver, pancreas, brain and glandular system. It crystallizes in whitish glistening laminæ, and is soluble in water and alcohol, but insoluble in ether. Little is known regarding the origin and physiological relation of these substances.

CHAPTER II.

ELEMENTARY OR PRIMARY FORMS OF TISSUE.

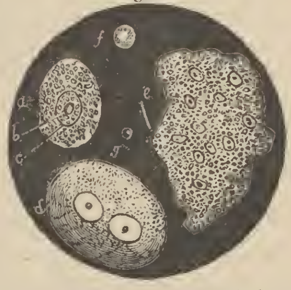
The elementary or primary forms of tissue are cells, granules, simple fibres, and simple or basement membranes. Of these, the cells are the most important, since they are the active agents in the performance of all the functions of the animal body, as digestion, absorption, selection, assimilation, respiration, secretion, excretion and reproduction. They also constitute the fundamental elements of all the tissues, and are the active agents in all the catalytic and chemico-vital changes which take place in the animal economy. The agency of cells is not only exhibited in the healthy actions of the body, but may also be seen in the development of various morbid growths, as fibroid tumors, cancer, etc. The form which organic matter takes when it passes from the condition of a proximate principle to that of an organized structure, is that of a cell, a simple fibre, or a simple membrane.

In all animal and vegetable tissues, there exists a soft gelatinous or albuminous substance called *protoplasm, sarcode, cytoplasm* or "*germinal matter*." It is transparent, of the same consistence in all parts of the body, and by the action of the vital forces may be formed into small rounded masses or cells, or thin hyaline membranes. It possesses properties and exhibits phenomena which are called *vital*, such as the movement of molecules in its substance, and the changes in the shape of the mass itself.

CELLS.

A cell may be defined to be a semi-solid rounded mass of protoplasm, or it may assume the form of a membranous sac enclosing protoplasmic or other contents. In the interior of most animals cells will be seen a small body termed the *nucleus*, and within the nucleus, a *nucleolus*; or there may be two or more nuclei, each containing one or more nucleoli.

Fig. 14.



(a)—Nerve cell. (b)—Nucleolus. (c)—Nucleus. (d) Ganglion corpuscle with two nuclei. (e)—Multinuclear giant cell from bone marrow, (Frey). (f) Blood corpuscle. (g) Fat globule.

Variation in Shape.—Cells are generally globular, but may assume various shapes, depending on internal and external circumstances, and the growth of the cell; for example, fat cells which are round when formed, may become polygonal as the result of mutual pressure (Fig. 9.) The specific gravity of the contents will also affect the shape to a considerable extent. When water is added they have a tendency to swell out and finally burst. When evaporation or desiccation takes place, they become flattened and hardened, as in the epidermis. The shape of the cell may also be changed by the absorption of gases and vapors, *e.g.*, the blood corpuscles present a distinctly biconcave disk under the influence of oxygen, and become rounded again when

exposed to the influence of carbonic acid gas. The vapor of ether, when inhaled, produces an irregular appearance of the blood corpuscles. Chloroform vapor causes a serrated outline, and alcohol renders them oval, with an indentation on one side.

Fig. 15.

Pigment Cells.

Cells may also assume different shapes, depending on their growth; for example, the pigment cell, which is at first spheroidal, throws out arms or projections in different directions, and becomes stellate during its growth. The nerve cell becomes unipolar, bipolar, or multipolar; nonstriated muscular cell, fusiform. Epithelial cells are either cylindrical (columnar), or squamous (tesselated or pavement.) In some instances, hair-like growths take place on the free surfaces or extremities of cells, as is seen in the cilia of epithelial cells. Some cells undergo a spontaneous change in shape, as the amœbæ, white corpuscles, etc.

Fig. 16.

(c)—Columnar epithelium of the intestines.
(d)—Columnar ciliated epithelium of the nose.

Variation in Size.—Cells vary in size from $\frac{1}{300}$ of an inch (83.5 mmm.) in diameter, the size of the largest fat cell, to $\frac{1}{20000}$ of an inch, (1.25 mmm.) the size of the fat globule. Some are so large as to be called giant cells, as those of bone marrow (Fig. 14, e.), and abnormal tumors, as cancer, sarcoma, etc. The average diameter of the red blood corpuscle is about $\frac{1}{3500}$ of an inch, (7 mmm). Nerve cells vary from $\frac{1}{300}$ to $\frac{1}{10000}$ of an inch (83.5 to 2.5 mmm; muscular fibre cells $\frac{1}{4500}$ to $\frac{1}{2500}$ of an inch, (5.5 to 10 mmm.) in diameter. The cell may be divided into a cell wall, nucleus, nucleolus and contents.

Cell Wall.—The cell wall, when present, is substantially the same in all cells, and is formed by the consolida-

tion of the outer surface of the mass of protoplasm. It is a simple homogeneous membrane, composed of globuline, and although no pores can be seen by the highest magnifying power, yet it possesses the property of osmosis. In some instances it is extremely thin; in others dense and unyielding. When the cell-wall is acted on by acetic acid, it swells out and becomes transparent, so as to bring into view the nucleus, when that body exists.

NUCLEUS.—In the interior of most animal cells is seen a small body, which is called the nucleus. It exists either in the form of a small vesicle, or as a small mass of protoplasm, containing one or more minute particles termed nucleoli. The nucleus is generally situated in or near the centre of the cell, but may be attached to the wall, or imbedded in it, as in the fat cell. It is generally rounded in form, but may be found elongated, as in the nonstriated muscular fibre cell. The size of the nucleus varies from $\frac{1}{4000}$ to $\frac{1}{6000}$ of an inch (6 to 4 mmm.) in diameter. It is more regular, both in shape and size, than the cell itself. In most instances each cell contains but one nucleus; cartilage cells frequently contain two or more. When two or more nuclei are found in one cell, it is generally an evidence of rapid growth, as in fibro-cellular tumors, cancer, pus, etc. In giant cells there may be a multitude of nuclei in each cell (Fig. 14 e.). They are, in these cases, formed by the subdivision of the original nucleus.

The nucleus resists the action of acids and alkalies better than any other part of the cell. It is readily stained by ammoniacal solution of carmine, and hence is regarded by Beale as *germinal matter* in contradistinction to the outer portion of the cell, which he calls *formed matter*.

Nuclei are sometimes found disconnected from the cells, when they are said to be *free*. They may be found floating in fluid as in certain secretions, or imbedded in a homogeneous pellucid substance, as in rudimental cellular tissue, or

on the surface of fibres, as in muscle and nerve fibres, in which they are either upon or immediately beneath the investing membrane. The nucleus is a most persistent little body, and retains its original form in many cases after the cell to which it belongs has ceased to exist as such.

NUCLEOLUS.—This is situated in the interior of the nucleus, and may consist of a single molecule, or a number united together. In some instances it is highly refracting, and not readily acted upon by most chemical re-agents. There may be one or more in each cell.

CONTENTS.—The contents of all cells consist of a certain amount of protoplasm mingled with other substances. Each cell has the power of generating in its interior a substance peculiar to itself, which is the result of its own secretion; one secretes bile, another milk, another mucus, another gastric juice, etc. The contents of the cell may be either solid, as in bone, nails, epidermis, etc., or fluid, as in blood, chyle, mucus, etc. The contents of all cells are fluid when formed, but become hardened by secondary deposit, as in bone, dentine, etc. This takes place by the deposition of solid particles in the interior of the cell.[1]

COLOR.—Cells are generally colorless; a few only have color which depends partly on their refracting power, and partly on the hemoglobine, melanine, or pigment which they contain, as the red blood corpuscles, pigment cells, etc.

PROTOPLASM, OR *Cytoblastema.*—This is the name given to the substance from which the cells spring, and is derived either from the fluid in which they float, as blood, chyle, lymph; or from the capillaries near the seat of growth. When the cells are situated on a basement membrane, as the epithelium of mucous and serous membranes, it is found surrounding them, having passed through the basement membrane from the capillaries immediately beneath. In all these cases the cytoblastema contains material not only to supply the wants of the present brood of cells, but also for the development of the new brood which is destined to take the place of the old.

The cell has also the power of choosing and refusing from the particles of nutrient fluid or cytoblastema in its neighbourhood, incorporating some of them into its substance, and converting others into new substances in its interior. For example, the blood corpuscle has the power of forming globuline and hemoglobine from the albumen and fibrin of the blood. It is contended by some physiologists that this power resides solely in the nucleus; but it must be borne in mind that this property belongs also to those cells which are entirely destitute of a nucleus, as the blood corpuscle, germ cells of the vegetable kingdom, etc.

CYTOGENESIS.—Κυτος "cell" and γενεσις "generation." Cells have their period of birth, growth, maturity, and decline. They spring up, perform their office, and then pass away. Some do so with great rapidity, while others are slower in their progress, or are longer lived. They are governed by certain laws, two of which we may here formulate.

1*st Law.*—In all tissues composed of cells, the new cells which are being developed must resemble the parent cells in all their distinctive features and properties. When the young cell deviates in its character from the parent cell, abnormal growth may be said to have commenced.

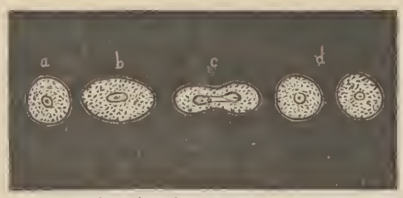
2*nd Law.*—Cell growth can only take place in or near its appropriate pabulum, and on living surfaces.

The mode of origin of cells takes place in several ways. Schleiden and Schwann, as far back as 1838, asserted that cells were developed *de novo* in an organizable blastema. According to this theory the cell was developed by the formation of granules in the blastema, their subsequent arrangement to form the nucleolus, around which at a certain distance was formed the nucleus, and lastly the cell wall and contents; or the order might be reversed by the formation, first of the cell wall, and subsequently the nucleus and nucleolus. This theory of *free cell formation* still has its advocates among many French physiologists, especially Robin.

According to the modern doctrine, which was first advocated by Virchow in 1852, every cell must originate from a *pre-existing* or *parent cell* (*omnis cellula e cellula.*) There are *three* different modes by which cells may be produced in this way.

1st. By *Multiplication by sub-division*, fission, or fissiparous multiplication of the cell. This process has been seen in the amœba, and in the blood corpuscles of the lower animals. The cartilage cell also furnishes a good example. The cell is originally rounded; but when the process of subdivision commences, it becomes oval, and subsequently presents a sort of hour-glass contraction, first of the nucleus, and afterwards of the cell. This continues until there is a complete separation, first of the nucleus into two parts, and then the cell, each part of the nucleus drawing a portion of the cell or cell-wall around it. This process may be again repeated in each part, either in the same direction or transversely, so as to form four new cells, and so on until a number have been produced. This is the mode by which segmentation of the vitellus takes place.

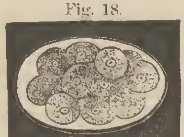
Fig. 17.



A cell undergoing the process of multiplication by subdivision. (a)—Original cell. (b)—Oval. (c)—Hour-glass contraction and division of the nucleus. (d)—Division of the cell into two.

2nd. By *subdivision of the nucleus* or contents of the cell only, the so-called endogenous mode. In this mode the nucleus appears to separate into two or more parts, each of which is developed into a new cell, and in this way the parent cell may be filled by a whole brood of young cells, the so-called daughter cells. This variety of cell development may be observed in bone cells, (Frey) also in structures of very rapid growth, as in cancerous tissue.

Fig. 18.



A cell containing a number of young cells.

3rd. By *gemmation* or budding. In this case a node or swelling is seen on one side of the cell which gradually in-

creasing, finally drops off by constriction at the base. The yeast cell is propagated in this manner.

Dr. Beale accepts the modern doctrine, and the term "protoplasm" as the substance from which cells are formed, but makes a distinction between the nucleus, which is readily stained with carmine, and the rest of the cell. He terms the nucleus "germinal" or living matter, in contradistinction to the outer portions of the cell, which he calls "formed matter," designating by the latter, the various tissues formed from cells.

CONDITIONS NECESSARY TO CELL GROWTH.—The conditions necessary to cell growth are the presence of protoplasm upon a living surface, a certain degree of animal heat, a requisite amount of water, oxygen, light and electricity. The dynamic agency of heat cannot be dispensed with; too much would be injurious. The mysterious influence of light is necessary to healthy action, and a certain amount of water is required to preserve the integrity and promote the growth of the cell; but too much would destroy it.

PERMANENT CHANGE IN THE SHAPE OF CELLS.—Cells undergo changes in the formation of tissues, and in the propagation of their kind, by which they lose their individuality as cells. This may be seen:

1st. By the process of cytogenesis, as in multiplication by sub-division etc., which has already been described.

2nd. By coalescence of the cell with the intercellular substance of temporary cartilage, as in the development of osseous tissue. (See development of bone.)

3rd. By the coalescence of cells, with the intercellular substance to form fibres as in fibrous tissue. The cells are originally round; but in the process of forming fibres they become elongated, and in some instances fusiform or stellate. They are then arranged longitudinally, sometimes slightly overlapping each other, and both the cells and the intercellular substance are broken up into fibrillæ.

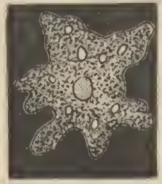
4th. By the coalescence of cells in a linear manner to form tubes. In this instance the opposing walls of the cells, as

they are arranged in a line, break down, the cavities of the cells communicate with each other, and in this way a continuous tube is formed, as in the development of muscular and nerve fibres, also in the formation of small vessels; or the cells may assume the form of curved plates or segments, united or cemented together in such a way as to form a tube.

Temporary Change in the Shape of Cells.—Temporary changes in the shape of cells give rise to motion. The cause of motion in the vegetable kingdom was for a long time a matter of speculation. It was finally discovered that this phenomenon was due to the change in the shape of the cells when irritated, as in the mimosa or sensitive plant, the fly-trap of the dionœa, and the berberis.

In the animal economy, muscular contraction is due to this temporary change. It occurs in both the striated and non-striated muscular tissue. In contraction of the fibrillæ the sarcous elements become shorter and broader; the same is true of the non-striated muscular fibre cells. Temporary changes in the shape of the cells take place in the uterus, during gestation. The cells are largely developed during pregnancy, in order to give enlarged accommodation for the fœtus, and increased power for the act of parturition. After birth the uterus undergoes the process of involution, by which the cells are diminished in size and number, and changed in their physical appearance. When examined by the miscroscope, oil globules may be seen in their interior at this stage. (Fig. 10.)

Fig. 19.



Amœba. In the centre is seen the nucleus, and surrounding it a number of vacuoles.

In some instances the change in the shape of the cell appears to be entirely of a spontaneous character, as in the amœba and white corpuscles of the blood, in both of which, changes in shape are constantly occurring at certain periods, and under certain circumstances.

The movements of the cilia of epithelial cells are no doubt also produced by the spontaneous change in the shape of the cells from which they

spring. These movements are probably caused by the alternate contraction and relaxation of the cells, and also of the cilia.

Cause of Organization, Vitality, &c.—This is a purely speculative subject. Many theories have been advanced from time to time, to endeavor to explain the phenomena of organized bodies. Some suppose that organization is due to an "animating principle" which pervades every organized structure and regulates its functions, and by which the new organism for the production of the species is moulded into shape, from materials furnished by the parent. This was the theory of Aristotle, and was afterwards advocated by Harvey. Hunter attributed the organization of living beings, and the vital action manifested by them, to a "materia vitæ" diffused throughout the solids and fluids of the body. Abernethy supposed this materia vitæ to be of a species of electricity. Mûller supposed that the cause of organization was due to an "organic force" which resides in the whole organism, and possesses the property of generating each part. This "organic force" exists already in the germ, and is creative, as is seen in the production and arrangement of cells to form the different parts of the new organism. It is not under the influence of the mind, as instinct is as capable of reproducing the species as higher intelligence. Prout advocated the existence of an "organic agent," which possesses extraordinary powers in controlling and directing the organization and development of the living being. This is very similar to the preceding hypothesis.

There can be no doubt, however, that organic matter derives its vital properties from a previously existing vital organism. While these organic matters retain a perfect organization, and are supplied with their proper stimuli, as light, heat, moisture, etc., vital actions go on perfectly: for example, the fecundated egg, "omne vivum ex ovo," acquires its vital properties while in the body of the mother; and

when laid, if supplied with the vital stimuli, and the organization remain perfect, it is developed into a new being. But as soon as the structure is destroyed, or the vital stimuli are withheld or withdrawn, the organism dies, and its elements form new compounds, most of which are of an inorganic character.

Function of Cells.—The function of cells is exhibited in the *plastic* and *metabolic*, or *vital* and *chemico-vital* power of the cell. The *plastic* power of the cell is seen in its development from protoplasm; the proliferation, by multiplication of new cells, their subsequent growth and development, and their transformation in the development of the tissues of the body.

The *metabolic* or chemico-vital power of the cell is shown in the property it has of chemically changing the protoplasm within and without the cell. It is confined to the conversion of special substances, as in the formation of globuline and hemoglobine, by the blood corpuscle, bile by the hepatic cell, and pepsine by the gland cells of the stomach, etc. The cell of the yeast plant has also the power of converting sugar into alcohol and carbonic acid. These two forces (plastic and metabolic) may act together: in fact, it is difficult to separate them, for while the cell is growing it is already beginning to perform its office. Both these forces act together in harmony, and through their united action the different secretions and excretions are formed. They are affected by nervous impressions, as fear, joy, grief, anger, etc. For example, the character of the milk is changed by a fit of anger, and the secretion of the gastric juice is arrested by fear.

The *plastic* and *metabolic* power of the cell may be arrested by powerful chemical re-agents, as arsenic, corrosive sublimate, acids and alkalies. It is also arrested by strong nervous shocks, as a stroke of lightning, or a powerful battery, and by septic poisons. The function of the cell is also further manifested in the permanent change it undergoes in the formation of tissues already described.

MANIFESTATIONS OF CELL LIFE.—These are exhibited:

First—In cell growth from protoplasm.

Second—In the multiplication or production of new cells.

Third—In the chemico-vital transformation of protoplasm

Fourth—In the permanent change in the cell.

Fifth—In the temporary change in the cell.

Sixth—In the production of nervous force (vis nervosa.)

A cell is a living organism, and like all living bodies, has its period of growth, maturity and decay. It has the power of selecting matters from the nutrient elements, assimilating and organizing them into new substances found in its interior. This property resides in the cell as a whole, and not exclusively in any single part of it. The duration of the life of a cell depends on its activity; those of slow development are long-lived, and *vice versa*. When a cell begins to decay, granular matter is first noticed in its interior; the cell wall or outer portion dissolves, and the cell finally disappears.

GRANULES.

Granules or *molecules* are minute particles of matter from $\frac{1}{10000}$ to $\frac{1}{25000}$ of an inch (2.5 to 1 mmm) in diameter. Some appear as dark specks, while others present a dark outline with a bright centre; this latter is characteristic of fat globules. They may be found incessantly moving about in the interior of cells, or in the fluids, as the granules of pigment cells, called pigment granules. They may exist either in the *free* state, as in chyle, milk, blood etc.; *inclosed* in cells, or *imbedded* in the tissues as in bone, dentine, cartilage. They are present in great abundance in chyle and give to that fluid its opalescent appearance (Fig. 7.) The molecules of chyle are of low specific gravity, readily soluble in ether, and are known as fat globules or granules.

SIMPLE FIBRES.

A simple fibre is formed by the arrangement and coalescence of granules or molecules in a linear manner. They

vary in size from $\frac{1}{10000}$ to $\frac{1}{20000}$ of an inch (2.5 to 1.25 mmm.) in diameter, and are rounded or prismatic in shape depending on pressure. They are formed in the coagulation or fibrillation of fibrin, and they constitute the primitive fibrillæ of striated muscular tissue. As coagulation of the fibrin takes place, star-shaped points are first formed, and the granules arrange themselves in a linear manner from one point to another and coalesce to form fibres, until the process is completed (Fig. 13.) This was formerly believed to be the mode of healing or organization in wounds and adhesive bands in inflammation, from the coagulable lymph or fibrin which was exuded from the blood-vessels for that purpose. The modern view regarding this subject, is that "coagulable lymph" is the product of the white corpuscles, which have passed through the coats of the vessels by virtue of their amœboid movements, supplemented by the proliferation of the connective tissue cells in the wounded or inflamed parts.

SIMPLE OR BASEMENT MEMBRANES.

These are formed directly from the nutrient fluid or protoplasm, by a certain arrangement of molecules peculiar to themselves. They are found in the walls of most cells, in the sarcolemma of muscular fibre, in the sheath of nerve fibre, in the covering of the vitreous humor, in the vitelline membrane of the ovum, and as the structure upon which the epithelium rests in membranous expansions. They exist under three different forms, which vary somewhat in microscopical appearance.

In the *first* variety, it is a simple pellicle of homogeneous appearance, and shows no sign of organization, as in the cell wall. A good example may be seen in the lining membrane of a bivalve shell. In the *second* variety, the membrane presents a number of minute granules irregularly scattered through the transparent substance. In the *third* variety, the membrane presents a number of distinct spots

or nuclei, and is capable of being torn up into portions of nearly equal size, each containing one of these spots or nuclei. From this it would appear that the *first variety* is formed by the condensation of a thin layer of protoplasm, the *second* by the condensation of a thin layer of protoplasm in which granules had been formed, and the *third* by the condensation of a thin layer of protoplasm in which nuclei had been formed.

Certain forms of membrane above described have been called by some *basement* membranes, because they are the foundation or resting place for the epithelial cells; by others, *primary, germinal*, or *maternal* membranes, because they furnish the germs of these cells. They are also called hyaline membranes, because of their structureless appearance. Basement membrane is found on all the free surfaces of the body, giving support to the epithelial cells. It forms the outer layer of the true skin, and the inner layer of mucous serous and synovial membranes, blood-vessels and lymphatics. It is also prolonged into all the ducts, follicles and tubuli connected with the mucous membranes. In all these examples its free surface is covered with cells, which receive their nutriment by osmosis, through the membrane, from the capillaries on its attached surface. Its *office* is to limit osmosis of the nutrient fluid, and to modify it in its passage. It also supports the cells, and probably determines the formation of all the cells which are developed on its surface. In all probability, the spots, or nuclei, seen in the basement membrane are the germs of cells, which spring from them as from a centre.

CHAPTER III.

TISSUES.

There are *seven* distinct tissues in the body viz : white fibrous or connective, yellow elastic, adipose, cartilage, bone (including dentine and enamel), muscle and nerve tissue, to which may be added gelatinous tissue and reticular connective tissue of modern histologists. All other tissues are made up of a combination of two or more of these. All, except muscular and nerve tissues are considered by some to be modified forms of connective tissue, and are described as the connective tissue group.

WHITE FIBROUS, OR CONNECTIVE TISSUE.

This tissue enters into the formation of ligaments, tendons aponeuroses and membranes.

1st. As *ligaments*, it connects the bones together and preserves the integrity of the joints in their various movements. The ligaments assume three different forms : *Funicular*, which consists of rounded cords of fibrous tissue, as the ligamentum teres. *Fascicular*, which consists of flattened bands, as the ligaments of the ankle, knee, and elbow ; and *Capsular*, which forms tubular expansions, as in the shoulder and hip joints.

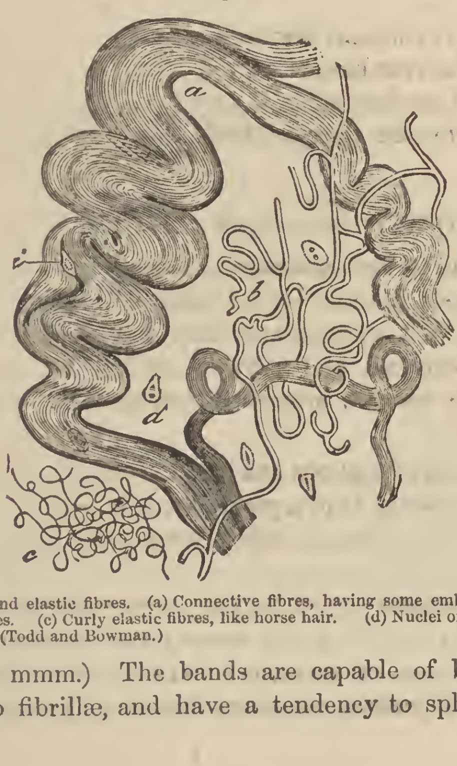
2nd. As *tendons*, it serves to connect the muscles to the bones and other structures to which they are occasionally attached ; some of these are round—*Funicular*, as the tendon of the semi-tendinosus ; others flattened—*Fascicular*, as the semi-membranosus. The tendons, at their insertion into the bones, blend with the periosteum.

3rd. As *aponeuroses*. These are tendinous expansions of considerable extent, as in the abdominal muscles. They serve to enclose cavities, and protect the contained organs.

4th. As *membranes*, it is used to cover, protect, and attach various organs, as the dura mater, sclerotic coat of the eye, pericardium, tunica albuginea testis, periosteum, perichondrium, fascia lata, &c. In all the above, a few elastic fibres are found associated with the white fibres.

PHYSICAL APPEARANCE AND PROPERTIES.—It presents a beautiful, silvery-white appearance, when freed from extraneous substances, and is composed of bundles of fibres, which are parallel to each other in some cases, and cross or interlace in others. Examined under the microscope, it is found to consist of wavy bands about $\frac{1}{500}$ of an inch (50 mmm) in diameter (Fig 20, a.) They are formed of numerous fibrillæ, varying in size from $\frac{1}{15000}$ to $\frac{1}{20000}$ of an inch

Fig. 20.



Connective and elastic fibres. (a) Connective fibres, having some embryonic globules. (b) Elastic fibres. (c) Curly elastic fibres, like horse hair. (d) Nuclei of cells, with nucleoli, × 320. (Todd and Bowman.)

(1.6 to 1.2 mmm.) The bands are capable of being separated into fibrillæ, and have a tendency to split up in a

longitudinal direction. When a portion is exposed to the action of acetic acid, it swells out and becomes semi-transparent, the fibrillæ are entirely obliterated, and a number of *connective tissue corpuscles* make their appearance, showing that it has been developed from cells. At the same time some wavy transverse lines may be seen at regular distances, which somewhat resemble striped muscular fibre. These lines mark the junction or outline of the cells from which the tissue was originally formed. A number of wandering cells (white corpuscles) and connective tissue corpuscles, are always found in connection with fibrous tissue. This tissue is somewhat elastic, and allows of a slight degree of extension from long-continued force. It possesses no contractility, and its force of cohesion is very great. It is said that the tendo-achillis is capable of supporting a weight of nearly 1,000 lbs. It contains few vessels and nerves. The actual presence of nerves has not, as yet, been satisfactorily demonstrated, and its sensibility is very low. The division of a tendon is attended with very little pain. It yields gelatine, on boiling.

YELLOW FIBROUS, OR ELASTIC TISSUE.

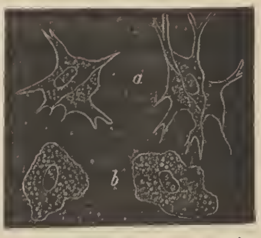
It is found in the ligamenta subflava, ligamentum nuchæ of quadrupeds, internal lateral ligament of the lower jaw, stylo-hyoid and pterygo-maxillary ligaments, chordæ vocales, crico-thyroid and thyro-hyoid membranes, posterior wall of the trachea, arteries, veins, thoracic duct, and in areolar tissue.

PHYSICAL APPEARANCE AND PROPERTIES.—This tissue, unlike the preceding, is of a yellowish color, highly elastic and consists of long, single, brittle fibres, with sharply defined dark borders, which show a disposition to curl upon themselves when broken (Fig. 20, b). They vary in size from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch (5. to 2.5 mmm.) the average diameter being about $\frac{1}{1500}$ of an inch (3.5 mmm.) and are round or flattened—depending on their situation or pressure. They

anastomose with each other, and are mingled in various proportions with the white, to form areolar or connective tissue. It yields a modified form of gelatine on prolonged boiling; is not acted on by acetic acid, and is not readily dissolved by the gastric juice. The fibres are stained red, with Millon's re-agent (a solution of proto, and pernitrate of mercury). It resists the approach of disease longer than any other tissue in the body; *e. g.*, an artery will remain intact in the interior of an abscess after the other structures are destroyed, and when the artery gives way, the walls present a honeycombed appearance, on account of the destruction of the white fibrous and muscular tissues with which it is associated. When dried it becomes dark colored, hard and loses its elasticity. It is sparingly supplied with blood vessels and nerves. The fibres are marked by transverse lines, in the lower animals, which shows that it is developed from cells. Its elasticity is impaired by age.

Mode of Development.—This is now believed to be the same in both connective and elastic tissue. They were supposed by Henlè to be developed by the process of fibrillation. Their real mode of growth was first pointed out by Schwann, to be from cells. The cells are at first round, and possess a nucleus, nucleolus and granular matter. They then become fusiform, or stellate, surrounded by intercellular substance, and being applied or spliced in a linear manner, coalescence takes place, and fibrillæ are formed (Fig. 21). At the same time the nuclei become elongated, and finally disappear, until brought into view by means of acetic acid. According to late observers a certain amount of material is formed by the cells, called *tissue cement* or *intercellular substance*, in which the cells become imbedded, and which serves to unite them together. This substance is blackened by nitrate of silver (Frey.)

Fig. 21.



Cells of human connective tissue. (a), flat stellate or shovel-shaped cells. (b), coarse granular cells.

Areolar Tissue, (Syn., cellular, connective or filamentous.) This tissue is found in all parts of the body except the brain, compact tissue of bone, teeth, cartilage, hair, nails, epidermis, etc. It consists of a network formed by a combination of white fibrous or connective tissue and yellow elastic tissue, together with a number of connective tissue corpuscles. Where great strength is required, the connective tissue predominates, and where motion is necessary, the elastic, as in the tissue of the lungs. The proportion of each may be easily demonstrated by acting on it with acetic acid, which dissolves out the white, while it produces no change on the yellow. The interstices or meshes (improperly called cells) of areolar tissue communicate with each other. This tissue, therefore, may be inflated with air (the butchers take advantage of this circumstance in inflating their meat), or the meshes may be filled with fluid, as in anasarca. The interstices, especially in the subcutaneous areolar tissue, are partially filled with fat cells, and contain a small quantity of serous fluid of an alkaline reaction, composed of water, albumen (.36 in 100) and sodium chloride. When the fat is absorbed by the demands of the system, its place is filled with serous fluid, as in phthisis.

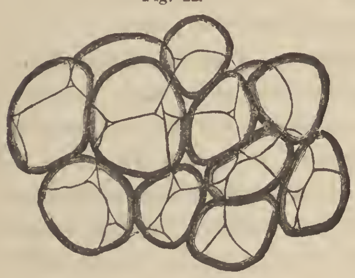
Function.—Its function is to surround and connect various organs, and retain them at certain distances; at the same time allowing a certain amount of motion. It also forms a nidus for the vessels and nerves, fills up spaces between different organs, and when the meshes are filled with fat, gives rotundity to the body. In some parts of the body it is very dense, and has received the name of a fibrous membrane, as in the pharynx, sheaths of vessels, etc. It forms sheaths for the muscles, and the bundles and fasciculi of which they are formed. It also forms sheaths for the vessels and nerves. It attaches the membranous expansions as the mucous, cutaneous, serous and synovial membranes, to the structures which they surround and embrace, and receives the name of sub-mucous, sub-cutaneous, sub-serous and sub-synovial areolar tissue, respectively.

ADIPOSE TISSUE.

This was formerly described as areolar tissue, with fat cells imbedded in its meshes. It exists however, in parts in which not the slightest trace of areolar tissue can be found, as, for example, in the cancellous tissue and marrow of bones. On the other hand, the areolar tissue in many parts of the body is entirely destitute of fat, as *e. g.*, beneath mucous membranes, in the cutis vera, between the rectum and bladder, in the cranial cavity, eyelids, epicranial aponeurosis, scrotum, penis, etc, but in other parts of the body they are associated together. Adipose tissue is found in abundance in the subcutaneous areolar tissue, called *panniculus adiposus.* It is entirely absent in embryonic life.

Physical Appearance and Properties.—It is composed of cells or vesicles containing fat, which vary in size from $\frac{1}{300}$ to $\frac{1}{800}$ of an inch (83 to 31 mmm) (Fig. 22.). They are usually deposited in clusters, being held together by a mesh of capillaries, which surrounds them, and from which they derive their nutriment. This constitutes a lobule. When the adipose tissue exists in considerable quantity, the lobules are held together by areolar tissue, constituting a *mass* of fatty tissue. It is abundantly supplied with blood-vessels, but no nerves or lymphatics have been traced into its substanee. At an early period of its formation, the cell or vesicle possesses a nucleus and nucleolus, the nucleus being imbedded in the cell-wall; but they disappear at maturity, being obscured by the oily contents of the cells. The cells or vesicles are round, when isolated, but become polyhedral from the flattening of their walls against each other. They are believed by some to ori-

Fig. 22.



Fat cells of adipose tissue.

ginate from connective tissue corpuscles by their transformation into fat cells. They are long-lived, and exosmosis of the fat is prevented by the constant moistening of their walls, by a thin serous fluid which surrounds them, on the same principle that a moist bladder will retain fatty matter, while a dry one allows it to exude. The cell wall in fat cells can be distinctly seen in a collapsed condition, after dissolving out the fat by means of ether ; the nucleus is then also readily seen by tinging with carmine.

Origin and Function.—This tissue is formed partly from the fat used as food, and also by a chemical transformation from the starch and sugar present in the different articles of diet. This process is accelerated by an imperfect supply of oxygen, as is seen in the fattening of animals which are closely penned up. It is also formed in the interior of most cells of the body, when undergoing retrograde changes, as in fatty degeneration. It fills up spaces otherwise unoccupied, gives rotundity to the body, forms a delicate pad or cushion to facilitate the action of movable parts, as at the base of the heart, behind the eye-ball etc., and from being a bad conductor of heat, it prevents its too rapid escape from the animal body. This is exemplified in those animals possessing little hair on their skin, in which there is a large quantity of adipose tissue beneath the integument. In other instances it gives ease to the gliding movements of parts, and protects them from the ill effects of sudden changes of temperature, as the adipose tissue of the omentum. As fat, it supplies combustible material for the maintenance of the animal heat of the body. It is stored away in the body, to be used, when necessary, to maintain animal heat, and as a source of nourishment, as in the hybernating animals, the process of absorption of fat being facilitated by the alkaline condition of the serous fluid by which the cells are surrounded. (See oils and fats).

CARTILAGE.

This is a very simple form of tissue, and is found in many parts of the body. In some of the lower animals, as fishes, the skeleton is formed entirely of this tissue, as the skate, sturgeon, etc.

PHYSICAL APPEARANCE AND PROPERTIES.—Its color varies from pearly white to light yellow, and it is possessed of a considerable degree of elasticity, flexibility and cohesive power. It yields chondrine, when boiled. Cartilage consists of cells imbedded in a hyaline or inter-cellular substance, or *matrix.* The cells are contained in cavities or lacunæ in the intercellular substance. Some of these cavities are lined by a thin membrane, the cartilage capsule; in other instances the cells appear to blend with the intercellular substance (Fig. 23). The cells are round or oblong, and vary in size from $\frac{1}{450}$ to $\frac{1}{2000}$ of an inch, (55.5 to 12.5 mmm). Each cell contains a nucleus and one or more nucleoli. The nucleus varies in size from $\frac{1}{2400}$ to $\frac{1}{4000}$ of an inch, (10 to 6.2 mmm.) and sometimes contains fat globules, as a result of some peculiar metamorphosis of the contents. Cell growth takes place by the process of multiplication by subdivision, and parent cells are frequently seen containing two or more young cells.

Fig. 23.

Hyaline (temporary) cartilage becoming transformed into bone substance. Hyaline substance with cartilage cells imbedded in it.

The intercellular substance is either homogeneous, granular, or fibrous.

Cartilage is divided into two great classes: *Temporary* and *Permanent;* the former constitutes the original frame work of the body, except portions of the vault of the cranium and bones of the face; and is supplanted by bone during development and growth; the latter is found in

different parts of the body and is not transformed into bone.

It is also divided into three classes according to the character of the intercellular substance, viz.: *Hyaline*, *elastic* or reticular, and *connective tissue* or fibro-cartilage.

HYALINE CARTILAGE.—This variety of cartilage embraces temporary, articular and costal cartilage, also the cartilages of the nose, larynx, trachea and bronchi, except the epiglottis and cornicula laryngis. In all these situations the intercellular substance is homogeneous or finely granular, but occasionally in old costal cartilage a few indistinct fibres may be seen. In temporary cartilage the intercellular substance is not very abundant; but the cells are numerous, and placed at nearly equal distances apart. They are rounded or oval, and vary in size from $\frac{1}{1500}$ to $\frac{1}{2000}$ of an inch, (16 to 12.5 mmm.) the nuclei being finely granular.

Fig. 24.

Cartilage cells in rows at the seat of ossification.

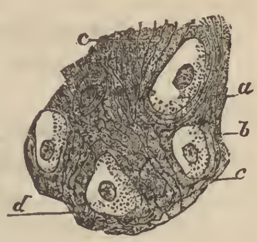
Near the seat of ossification the cells are arranged in rows, running towards the ossifying part, and become hardened by interstitial or secondary deposit of calcareous salts (Fig. 24). In the cartilage of the ear in rats, mice, and other small animals, and also in the human chorda dorsalis in early fœtal life, the intercellular substance is very small in quantity and the cells are closely packed together. This constitutes the so-called cellular cartilage.

In articular cartilage which is found in joints, covering the articular surfaces of bones, the intercellular substance is more abundant than in temporary cartilage, and presents a finely granular appearance. The cells are rounded or oval, varying in size from $\frac{1}{1300}$ to $\frac{1}{900}$ of an inch (19 to 27.8 mmm). Near the surface of the cartilage, the cells are

numerous, and arranged in flattened groups, lying with their planes parallel to the surface. This appearance has been mistaken by some physiologists for a layer of epithelium. In the interior of the cartilage, the cells assume a linear direction pointing towards the surface. This serves to ex-explain the disposition this form of cartilage has, to split up in a direction perpendicular to the surface. In costal cartilage, the intercellular substance is very abundant, finely mottled and sometimes indistinctly fibrous. The cells are larger than in any other cartilage of the body, being from $\frac{1}{650}$ to $\frac{1}{450}$ of an inch (38 to 55.5 mmm) in diameter. Some contain two or more nuclei, which are transparent, and others contain nuclei and fat globules. The cells often assume a linear arrangement, the rows being turned in different directions—probably the result of the growth of the cells by subdivision from the parent cell, and their subsequent separation from each other in a linear manner. Calcification of cartilage sometimes occurs. It consists in a deposition of lime salts around the cells or cell groups, until the whole intercellular substance presents a dark granular appearance (Fig. 29.) This calcified cartilage, however, does not become bone.

Elastic or Reticular Cartilage.—This is of a yellowish color, arranged in the form of plates or lamellæ of various thickness, and enters into the formation of the external ear, epiglottis, cornicula laryngis, Eustachian tubes etc. These plates serve to maintain the shape of tubes or passages, which require to be kept open, without the expenditure of vital force. It approaches in character to the fibro-cartilage. The intercellular substance is permeated by a clear network of fine elastic fibres. The cells are numerous and vary in size from $\frac{1}{1300}$ to $\frac{1}{900}$ of an inch (19 to 27.8 mmm.) in diameter (Fig. 25).

Fig. 25.



Elastic Cartilage; (a) cells; (b) intercellular substance; (c, d,) elastic fibres of the latter. Frey.

CONNECTIVE TISSUE—OR FIBRO-CARTILAGE.—Fibro cartilage consists of a mixture of connective tissue and cartilage cells in various proportions. It exists in four forms, *Interarticular, Connecting, Circumferential* and *Stratiform.*

The *interarticular fibro-cartilages* are flattened lamellæ of different shapes, placed between the cartilages of the temporo-maxillary, sterno-clavicular, acromio-clavicular, wrist and knee-joints. They are free on both surfaces; thinner at the centre than at the circumference, and are held in position by the surrounding ligaments. Their use is to increase the depth of the articular surfaces; to moderate the effects of great pressure; as a cushion, to deaden the intensity of shocks; to give ease to the gliding movements of these joints; and to increase the extent of the synovial membrane for secretion.

The *connecting fibro-cartilages* are placed between the bony surfaces of those joints which possess very little mobility; as between the bodies of the vertebræ, and the symphysis of the pubes, and serve to connect them together. They are in the form of discs, composed of concentric rings of fibrous tissue and cartilaginous laminæ placed alternately; the former predominating towards the circumference; the latter, towards the centre.

The *circumferential variety* consists of a rim of fibro-cartilage which surrounds the margin of some of the articular surfaces, and serves to deepen the cavity; as, *e.g.*, the glenoid and cotyloid cavities.

The *stratiform fibro-cartilage* lines the grooves through which the tendons of certain muscles pass; as *e.g.*, the bicipital groove.

VASCULAR SUPPLY.—Cartilage is chiefly supplied by imbition. It is covered by a layer of white fibrous tissue, containing vessels, called the perichondrium, which corresponds to the periosteum of bones. From this covering the cartilage receives its nutriment. When the cartilage is thin no vessels penetrate it; but when it is more than $\frac{1}{8}$ of an

inch in thickness as in costal cartilage it contains canals for their transmission.

Articular cartilage is not covered by perichondrium. It derives its nutrition by imbibition from the vessels of the synovial membrane which skirt the circumference of the cartilage, and also from those of the cancelli of the adjacent bone, which are separated from the cartilage by the articular lamella. The vessels of the synovial membrane pass forward to the margin of the cartilage, and then return in loops, and those of the cancellous tissue pass to the internal surface of the articular lamella, form arches, and return to the substance of the bone.

Fibro-cartilage is supplied by the vessels of the synovial membrane and perichondrium, with which it is invested.

GELATINOUS AND RETICULAR CONNECTIVE TISSUES.

Gelatinous tissue constitutes the semi-solid substance which forms the vitreous humor of the eye, and the jelly-like substance which covers the umbilical cord (Whartonian jelly). It consists of a soft homogeneous intercellular substance in which are imbedded a number of rounded transparent cells. A higher development of the gelatinous tissue is found in the so-called enamel organ of the growing tooth. The cells in this case are stellate in form.

Reticular connective tissue is found in the lymph glands, and lymphoid organs, as the tonsils, thymus gland, Peyers glands, Malpighian corpuscles of the spleen, etc. It consists of a delicate areolar tissue in the meshes of which lie innumerable lymphoid cells (white corpuscles). It is sometimes called adenoid tissue, and is believed to be a modified form of connective tissue. It is built up of stellate nucleated cells, the arms of which are united like threads, and form meshes in which the lymphoid cells are situated. The meshes are usually rounded, but may assume an elongated form.

BONE.

This constitutes the solid frame-work of the body. It forms organs of support, levers for motion, or it encloses cavities, and protects delicate organs, as the brain, heart, lungs, &c.

PHYSICAL APPEARANCE AND PROPERTIES.—It is a hard, dense, opaque substance, of a whitish color, and possesses a considerable degree of elasticity. It consists of an *organic or animal*, and an *inorganic or earthy* material, intimately blended together; the animal matter giving to the bone its elasticity and toughness; the earthy part its hardness and density. The animal matter may be separated from the earthy, by steeping the bone in dilute nitric or muriatic acid. In this way the earthy matter is dissolved out, and the bone becomes quite pliable—so much so, that the fibula, if so treated, can be drawn into a knot. The earthy constituents may be obtained by burning the bone in an open fire. By this means the animal matter is entirely consumed, and the earthy part remains as a white brittle substance. The relative proportion of these two substances varies in different persons, and in the same person at different periods of life. In the child, the animal matter forms about half the weight of the bone; in the adult about $33\frac{1}{3}$ per cent., and in old age about 25 per cent. In certain diseases of the bones, as rachitis or "rickets" and mollities ossium, there is a deficiency of earthy matter, and in fragilitas ossium, a deficiency of animal matter. Bone, when boiled, yields *gelatine*, and from the earthy matter may be obtained granules, from $\frac{1}{6000}$ to $\frac{1}{14000}$ of an inch, (4. to 1.7 mmm) in diameter.

CHEMICAL CONSTITUENTS.—In 100 parts:—

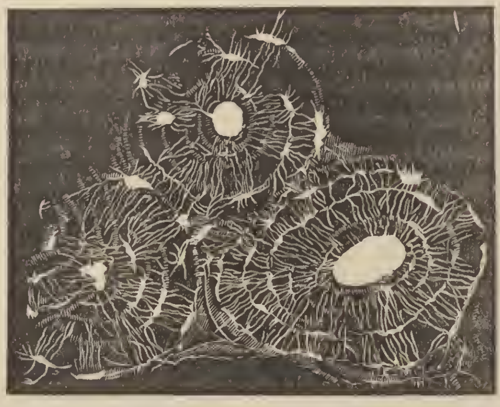
Organic matter—Areolar tissue, Blood-vessels, Nerves and Fat		33.30
Inorganic or Earthy matter.	Lime Phosphate	51.04
	Lime Carbonate	11.30
	Calcium Fluoride	2.00
	Magnesium Phosphate	1.16
	Soda and Sodium Chloride	1.20
		100.00

STRUCTURE OF BONE.—Bone presents two varieties of osseous tissue. The one is dense, firm and compact, and always situated on the exterior of the bone, called the *compact tissue;* the other, loose and spongy, enclosing cells or cancelli, and situated internally, is called the *cancellous tissue.* In the extremities of the long bones, the cancellous tissue is most abundant, while in the shaft the compact tissue predominates. In short and flat bones, the two varieties are more evenly distributed. The external surface of the compact tissue (except the articular lamella) is covered by a dense fibrous membrane, the periosteum. The interior of the long bones in adult life, presents a cavity called the medullary canal. This is filled with the so called marrow, which is of a reddish or yellow color, and consists of vessels, nerves, delicate areolar tissue, fat cells, and a number of lymphoid cells. The latter are believed, by some, to be transformed into red blood corpuscles. There are also near the surface of the bone marrow, a number of myeloplaxes or giant cells (Fig. 14 e.) The cancellous tissue also contains marrow. The periosteum is abundantly supplied with blood vessels, and is intimately attached to the bone; and if separated to any great extent, the bone perishes. It also sends prolongations, accompanied with vessels, through numerous foramina in the bone into the canals of the compact tissue for its supply. It is now settled that the medullary cavity is not lined by a membrane corresponding to the periosteum (endosteum), the marrow being applied directly to the bone.

If a transverse section from the shaft of a long bone be examined under the microscope, a number of apertures, surrounded by a series of concentric rings, may be seen. These apertures are sections of the medullary or Haversian canals (named after the discoverer, Clopton Havers), and the rings are sections of the lamellæ which surround the canals. Surrounding the Haversian or medullary canals, in a concentric manner, may be seen a series of dark spots or centres, called lacunæ. These communicate with each other, and with the

Haversian canals, by minute tubes, called canaliculi or pores. The whole constitutes a Haversian system, and is a provision made for the supply of the compact tissue.

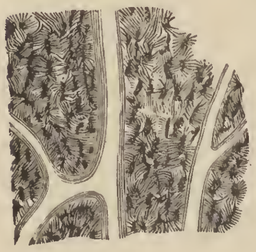
Fig. 26.



Transverse section of the shaft of the humerus × 150. Three Haversian canals are seen with concentric rings; also the corpuscles or lacunæ with the canaliculi extending in all directions.

The Haversian canals in the long bones run nearly parallel to each other and to the long axis of the bone; but in the irregular and flat bones, they are irregular in their direction. They vary in size from $\frac{1}{200}$ to $\frac{1}{2000}$ of an inch (125 to 12.5 mmm) and communicate freely with each other and with the outer and inner surfaces of the compact tissue, by means of transverse and oblique canals, (Fig. 27). They give passage to small arteries and nerves for the supply of the bone. The small arteries are derived from the nutrient artery, the vessels of the periosteum and marrow. The laminæ which surround the Haversian canals vary in number from 8 to 15, and are called the Haversian lamellæ. Besides these, some appear to be arranged concentrically, around the medullary canal or marrow of the shaft; these are called circumferential, and others

Fig. 27.



Longitudinal section of bone, showing the Haversian canals and their branches.

are situated between the Haversian systems, called interstitial lamellæ.

LACUNÆ —The lacunæ, or bone cells are arranged in concentric circles around the Haversian canals. They are small cavities of a semi-lunar shape, the concavity being turned towards the Haversian canals, and vary in size from $\frac{1}{1500}$ to $\frac{1}{2000}$ of an inch, (16.5 to 12.5 mmm). They are reservoirs for the plasma of the blood, previous to its absorption by the tissue, and each contains a nucleated membraneless cell,or bone corpuscle, which is homologous with the connective tissue corpuscle, and which in all probability sends prolongations into the canaliculi.

Fig. 28.

A lacuna from the ethmoid bone of the mouse; a, basis substance; b, the bone cell.

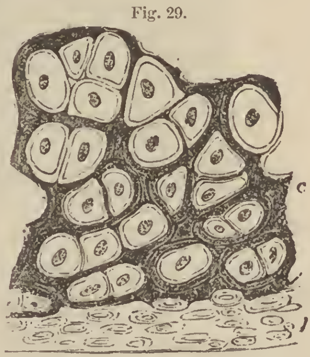
CANALICULI.—These are small tubes or pores, which issue from all parts of the circumference of the lacunæ. They communicate with those from adjacent lacunæ, and some open on the free surface of the bone. By this arrangement, the plasma of the blood is carried into every part. They vary in size from $\frac{1}{15000}$ to $\frac{1}{20000}$ of an inch (1.65 to 1.25 mmm.) in diameter.

In cancellous tissue, and in the *articular lamella* which supports the articular cartilage, there are no Haversian canals, and the lacunæ are larger than ordinary.

DEVELOPMENT.—Bone is not directly formed from temporary cartilage, as was formerly supposed.

Ossification commences in the cartilage at certain points, called points or centres of ossification, but the calcified cartilage (Fig. 29) does not become bone. It dissolves away, and in the system of cavities thus formed the bone substance is developed from the periosteum.

Fig. 29.



Section of diaphysis of cartilage; c, calcified cartilage; p, perichondrium.

In long bones there is usually a central point for the shaft, and one for each extremity. The central point is called the *diaphysis*, the extremity the *epiphysis*. The point of ossification of a process, as, *e. g.*, the olecranon, is also called the epiphysis, and when finally joined to the shaft, an *apophysis*. The period at which ossification begins, varies in different bones. The earliest is the clavicle, which begins about the fourth week of fœtal life ; next, the lower jaw, then the ribs, vertebræ, femur, humerus, tibia, upper jaw, etc., in order of succession.

Fig. 30.

Section of epiphysis showing the process of ossification. 1.—Cartilage cells imbedded in hyaline substance. 2.—Cavernous tissue, the calcified cartilage having become liquefied. 3.—Ossifying portion. (a)—Cavernous or medullary spaces shown empty. (b)—The same filled with cells, (c)—Remains of the calcified cartilage. (d)—Medullary spaces in which lamellæ of bone tissue have been formed from the osteoblasts. (e)—Developing bone cell. (f, g, h)—Imbedded bone cells or lacunæ.

In the transformation of temporary cartilage into bone preparatory changes take place which consist in its becom-

ing soft and vascular, the vessels growing in from the perichondrium. The cartilage cells multiply and form cylindrical piles or columns, (become ranked), separated from each other by trabeculæ of intercellular substance which is becoming calcified (Fig's. 24 and 30). The calcified substance soon after liquefies in places so as to form cavernous spaces or areolæ, which contain groups of cartilage cells, and basis substance. The cells next the periphery of these cavernous or medullary spaces and which resemble a layer of epithelium, become altered in shape and are called osteoblasts. These coalesce with each other and with the intercellular substance to form the *first* lamella of bone tissue; while here and there one of the osteoblasts is pushed out of line or indented, and forms a lacuna or bone corpuscle. This process is again and again repeated by the production of cells from the basis substance until the formation is completed. Each lacuna throws out arms or projections in different directions, which meet others from adjacent lacunæ, and in this way canaliculi or pores are formed. This endochondral bone which is so irregular and cavernous, is very different however from the beautiful regularity of permanent bone tissue. It undergoes a change. According to some the endochondral bone becomes liquified and absorbed in order to permit of the formation of medullary canals, and a new formation of bone takes place from the periosteum, into which the perichondrium has been changed. Others deny the liquefaction theory, and maintain that the change is due to interstitial growth alone; we rather incline to the absorption theory. It is now a well known fact, that living periosteum has the power of generating bone tissue, from the osteoblasts of its deepest layer. According to the absorption theory, while the liquefying process is going on in the endochondral bone, the osteoblasts of the periosteum grow downwards in cones (osteoblast cones.) These osteoblast-cones producethe Haversian lamellæ, while the flat osteoblast layer immediately beneath the periosteum forms the general or circumferential lamellæ. This also explains

the increase in thickness of the bone during growth and development. During ordinary repair, absorption from within and deposition from without are continually going on.

The ossification in the vault of the cranium and bones of the face, in which there is no temporary cartilage, is called *intra-membranous* or ectosteal, in contradistinction to *intra-cartilaginous* or endosteal. These bones are formed from a soft, fœtal connective tissue in which are found nuclei and osteoblasts, the process of origin of bone being the same as when formed from periosteum. Some modern investigators also favor the view that bone may be formed by the direct transformation of cartilage into bone tissue, or by the deposition of calcareous matter in connective tissue. The latter may be the explanation of the formation of the so-called callus in the repair of bone.

Growth.—The growth of bone takes place by layers formed in succession on its external surface—*exogenous*—and also in an interstitial manner. Bones increase in length by additions between the points of ossification, and by accessions of osseous tissue to the extremeties. This may be shown by inserting metallic pegs in the shaft at certain distances apart, when it will be seen that, notwithstanding the increase in length of the bone, the distance between them remains the same.

Bones increase in diameter, by additions of osseous tissue on their exterior. The osseous tissue thus added is not a mere lamina of bone, but consists of complete Haversian systems, the earlier systems being covered over by the more recent ones. This may be demonstrated by feeding animals with madder. The coloring principle is precipitated with the lime phosphate, and on examination, beautiful crimson rings are seen encircling the Haversian canals. This appearance is confined chiefly, to the external or vascular surface. When the madder has been given at intervals, colored and colorless portions alternate with each other. The color remains a long time, indicating a slow change of this tissue.

In early life there is no medullary canal in the shaft of the long bones, its place being filled with cancellous tissue. This tissue, however, becomes gradually absorbed as age advances, until about the twenty-fourth year, when the canal is completely formed and filled with marrow.

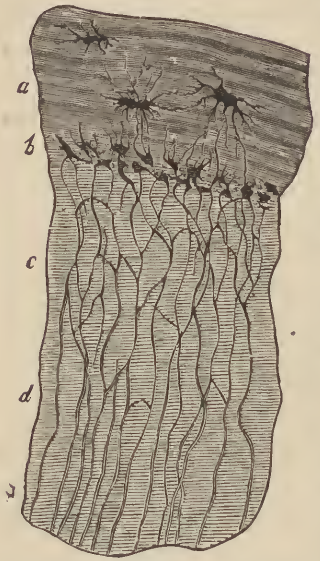
TEETH.—There are two sets of teeth with which the human subject is provided. The first set appear in childhood and are called *temporary* or *deciduous* teeth. They are twenty in number,—four incisors, two canine, and four molars in each jaw. The second set are called *permanent*, and are thirty-two in number,—four incisors or front teeth two cuspids (one on each side of the incisors), four bicuspids two on each side), and six molars (three on each side), in each jaw. Each tooth consists of the *crown* or exposed part, the *neck*, the constricted part beneath the gum, and a single or multiple *fang* or root imbedded in the jaw, and contains within it a pulp cavity. The bicuspids, and the molar teeth of the lower jaw, have each two fangs; the molars of the upper jaw, three.

The pulp consists of vessels, highly sensitive nerve filaments and areolar tissue, which enter by an opening at the extremity of the fang. It also contains dentinal cells or odontoblasts, from which the dentine is formed. These odontoblasts are oval in shape, $\frac{1}{1200}$ to $\frac{1}{800}$ of an inch (2 to 3 mmm) in diameter, and send some of their fine thread-like processes into the dentinal tubuli. The pulp cavity may be compared to the Haversian canals of bone. The solid structure of the tooth is composed chiefly of *dentine*, covered with a thin layer of *enamel* on the crown, and bone tissue (crusta petrosa) on the fang.

Dentine consists of minute, wavy tubes, *dentinal tubuli*, which lie parallel to each other and open into the pulp cavity, being arranged vertically on the summit, and horizontally on the sides. The tubuli are about $\frac{1}{25000}$ to $\frac{1}{12000}$ of an inch (1 to 2 mmm.) in diameter, and are imbedded in a dense, homogeneous substance—the intertubular tissue or matrix. They divide and subdivide dichotomously

as they pass towards the surface, sometimes terminating in inter-globular spaces resembling lacunæ, and convey nourishment for the supply of the enamel. The chemical composition of dentine is similar to bone, with a predominance of the earthy matter, in the proportion of seventy-two earthy, to twenty-eight per cent. animal matter.

Fig. 31.



Section of tooth fang. a, Crusta petrosa, or cement covering; b, granular or Tomes' layer with interglobular spaces; c, dentine; d, dentinal tubuli.

Sometimes the matrix presents lamellæ arranged concentrically with the pulp cavity.

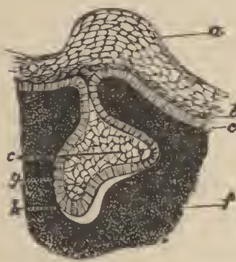
Enamel is the hardest tissue of the body, and forms a covering to the dentine of the crown of the tooth. It consists of a congeries of minute, solid, hexagonal rods, which are parallel to one another, resting by one extremity, on the dentine, the other being covered by a tough membrane $\frac{1}{15000}$ to $\frac{1}{30000}$ (1.6 to .8 mmm.) of an inch in thickness, called the *cuticle of the enamel.* They are arranged vertically on the summit, and horizontally on the sides, like the dentinal tubuli, and are about $\frac{1}{5500}$ to $\frac{1}{7000}$ of an inch (4.5 to 3.6 mmm.) in diameter. Small spaces are left between the rods at the dentinal surface to allow of the permeation of fluids from the dentinal tubuli, for the supply of the enamel. It consists of 96.5 parts earthy, and 3.5 parts animal matter.

The *bone* covering the fangs is called *crusta petrosa,* or cement covering. In structure and chemical composition it resembles true bone, but without any lamellar arrangement or Haversian canals.

Development of the Teeth.—The teeth are essentially dermal structures which have become calcified, the

epithelium forming the enamel, and the subjacent tissue, the dentine and cement. About the sixth week of fœtal life, a rounded thickening or projection of the superficial layers of the epithelium of the jaw, appears all around the free border. At the same time the deep layer dips down into the subjacent tissue in the form of a wedge, and forms the 'primary' enamel germ (Fig. 32). Here and there in the mucous tissue of the jaw, corresponding to the number of teeth, a convex papillary structure, the tooth germ, grows upwards towards the enamel germ, and pushes in or indents its under surface, so as to give it the form of a cap or bell. This is the enamel organ. The germs of the teeth continue to grow and are soon enclosed in sacculi, (Fig. 33).

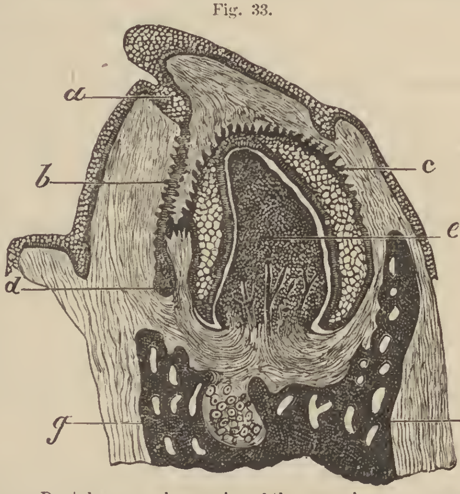
Fig. 32.



a, Epithelium; b, younger layer; c, inferior layer; e, enamel organ; f, dentine germ or papilla; g and h, inner and outer layers of the forming sacculus.

Development of Enamel.—The enamel is developed from petrified or calcified epithelium. The enamel organ becomes separated from the point of origin in the epithelium of the jaw. It is lined throughout with cylindrical and hexagonal epithelial cells, covering the surface of the tooth germ, and reflected at its base upon the inner surface of the sacculus. The space between these two layers is filled with a

Fig. 33.



a, Dental groove; b, remains of the enamel germ; c, enamel organ lined with epithelium on its outer (saccular) and inner (papillary) surfaces; d, enamel germ of the permanent tooth; e, dentine germ; f, section of inferior maxilla; g, Meckel's cartilage.

gelatinous tissue, which is the pabulum of the columnar enamel cells, and contains a few stellate cells. These columnar cells upon the surface of the tooth germ become calcified, and form the enamel rods which are completed by the superposition of cells, and their subsequent calcification.

Development of the Dentine.—The dentine is developed from the odontoblasts of the tooth germ, by a process of calcification. It commences as a dark area, at the base of the enamel germ. As development proceeds, the cells or odontoblasts become elongated and arranged in a linear manner vertically to the surface of the tooth germ; the outer portions of the cells become calcified and form the intertubular tissue or matrix, while the central part remains unchanged, and forms the dentinal canals. This process gradually extends inwards while the vessels, nerves, and areolar tissue recede until they come to occupy the central part, which is called the pulp cavity. About the fifth month, and prior to the calcification of the temporary teeth, a "secondary" enamel germ begins to form on the inner side of the original one for the production of the "permanent" teeth. These pass through the same phases of development as those already described as the temporary set.

Eruption.—When the tooth is sufficiently hard to enable it to pass through the gum, the eruption takes place. The gum is absorbed by the pressure of the tooth against it, which is itself pressed up by the increasing size of the fang. The septa between the dental sacs, at first fibrous, soon ossify, and constitute the septa of the alveoli in which the fangs are lodged.

Periods of eruption of the temporary teeth.—The teeth of the lower jaw precede those of the upper.

Central Incisors	7th	month.
Lateral "	7th to 10th	"
Anterior Molars	12th to 14th	"
Canines	14th to 20th	"
Posterior Molars	18th to 36th	"

Periods of eruption of the permanent teeth :

First Molars	$6\frac{1}{2}$	years.
Middle Incisors	7	"
Lateral "	8	"
First Bicuspids	9	"
Second "	10	"
Canines	11 to 12	"
Second Molars	12 to 14	"
Wisdom Teeth (Dentes Sapientiæ)	17 to 21	"

The teeth of the lower jaw, also precede those of the upper in the permanent set.

MUSCLE.

Many cells of the body, and certain tissues possess the power of changing their form, from time to time, as the white corpuscles, cartilage cells, cilia, spermatozoa, connective tissue, etc., but the muscles are alone those organs by which the various movements of the body are effected. They possess the property of contractility and are the active organs of locomotion. Muscular tissue is divided into two varieties, *Striated* and *Non-striated.* They may be distinguished from each other—1st. By their color; the striated are reddish in color, while the nonstriated are pale. 2nd. By the aid of a microscope; the striated muscular fibres are characterized by being marked with transverse lines or striæ; other striæ pass longitudinally, indicating the direction of the fibrillæ. The nonstriated muscular tissue consists of pale-colored fusiform fibre cells. 3rd. By galvanism. The striated respond to galvanism instantly, by a clonic spasm, while the nonstriated respond slowly by a tonic spasm. Muscular tissue is also divided into *voluntary* and *involuntary,* according as it is under the control of the will, or independent of it.

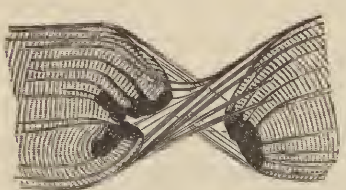
STRIATED.—This variety of muscular tissue comprises the whole of the voluntary muscles, the diaphragm, muscles of the ear, tongue, pharynx, upper part of the œsophagus, heart, and the veins, at their entrance to the heart. When

a transverse section of a muscle, as the sartorius, is examined by the microscope, it appears to be formed of a number of large bundles of muscular tissue, enclosed in a coat of areolar tissue, which constitutes the sheath or perimysium externum of the muscle. Each larger bundle consists of numerous smaller ones, enclosed in a similar covering of connective tissue, called the perimysium internum. Each smaller bundle contains the *primitive fasciculi or fibres*, and each primitive fibre contains the *primitive fibrillæ*.

In the spaces between the bundles may be seen the vessels and nerves for the supply of the tissue.

The Primitive Fasciculi or Fibres.—Each primitive fibre contains a number of primitive fibrillæ, and is surrounded by a sheath of transparent homogeneous membrane, the *myolemma* or *sarcolemma*. Resting upon, and sometimes beneath this membrane may be found here and there, oval nuclei surrounded by a small quantity of protoplasm. The primitive fibres are cylindrical or prismatic in shape, and vary in thickness from $\frac{1}{200}$ to $\frac{1}{500}$ of an inch (125 to 50 mmm); their length does not exceed on an average one inch and a half. They are marked by fine, dark, wavy, or curved parallel lines or striæ, from $\frac{1}{10000}$ to $\frac{1}{12000}$ of an inch apart (2.5 to 2.12 mmm), which pass transversely around them; this is characteristic of this variety of muscular tissue. Other lines, less distinct, run longitudinally, indicating the direction of the fibrillæ of which the fibre is composed. They have a tendency to split both in a transverse and longitudinal direction, but cohesion is greatest in the former direction.

Fig. 34.



Muscular fibre torn across; the sarcolemma still connecting the two parts of the fibres.

The Primitive Fibrillæ.—These constitute the proper contractile tissue of the muscle. They are cylindrical or prismatic, sometimes flattened—depending on pressure—

vary in thickness from $\frac{1}{10000}$ to $\frac{1}{18000}$ of an inch (2.5 to 1.4 mmm.), and are marked by transverse striæ with which those on the surface of the fasciculi correspond. Each fibrilla consists of a single row of minute particles, named "*sarcous elements,*" connected together like a string of beads. When examined by the microscope the sarcous elements present a rectangular outline, and the fibrillæ appear to consist of light and dark particles or zones placed alternately; hence their striated appearance. The dark particles correspond with the sarcous elements, and the light ones with the junction of the pairs. They somewhat resemble a Volta's pile. The transverse striæ, vary from $\frac{1}{10000}$ to $\frac{1}{12000}$ of an inch apart in the human subject; in birds $\frac{1}{10400}$, in reptiles $\frac{1}{11500}$, in fish $\frac{1}{11000}$, and in insects $\frac{1}{9500}$ of an inch, (2 to 3 mmm.) When examined with a high magnifying power, a dark line, with granules above and below, is seen to cross the middle of each light particle, known as Krause's transverse lines or intermediate discs. The granular appearances above and below, are called secondary discs. A white line has also been observed to cross the middle of the dark zones, known as Hensen's median disc. Late researches have also shown that each fibrilla is surrounded by an extremely thin membrane. This is an argument in favor of the view, that the fibrilla is the *anatomical* element of muscular tissue. The striated muscle of the tongue and heart of the mammalia and man, is somewhat different from that generally met with. The fibres are not arranged in bundles, and surrounded by connective tissue, but weave or interlace among each other. They also anastomose with each other, so as to form a narrow-meshed net work, and there is no appearance of sarcolemma.

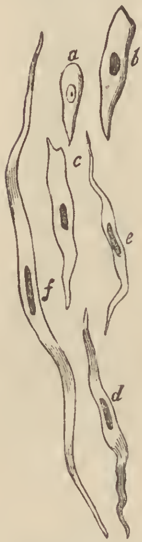
Fig. 35.

Fibrillæ magnified 800 diameters; a, a, larger, and b, b, smaller bundles; c, still smaller; d. d, the smallest representing a single series of sarcous elements (Sharpey).

NONSTRIATED.—This variety consists of flattened bands,

or elongated fusiform fibre-cells, of a pale color, from $\frac{1}{4500}$ to to $\frac{1}{3000}$ of an inch (5.5 to 7.5 mmm) broad, finely granular and containing a rod-shaped nucleus, which sometimes appears as a streak (Fig. 36). These fibre-cells may assume different shapes; they are generally fusiform, but some are club-shaped, and others of a rectangular shape, with fringed extremities. The length of these fibre-cells is from $\frac{1}{50}$ to $\frac{1}{1000}$ of an inch (500 to 2.5 mmm.) They are held together by connective tissue, and the bands are applied to each other in such a way, as to encircle the organ into the formation of which they enter. This kind of tissue is found in all hollow organs (except the heart and veins attached), as the ducts of the salivary glands, trachea and bronchi, alimentary canal, from the lower part of the œsophagus to the internal sphincter, gall bladder and ducts, calyces and pelvis of the kidney, ureters and bladder, and in the urethra. In the female; in the vagina, uterus, Fallopian tubes and round ligaments. In the male; in the scrotum, epididymus, vas deferens, vesiculæ seminales, prostate and cavernous bodies, in the coats of arteries, veins and lymphatics; in the iris and ciliary muscle, and in the integument called the *arrectores pilorum*.

Fig. 36.



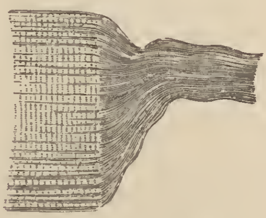
Nonstriated muscular fibre cells. a, Developing cell from the embryo of the hog; b, a more advanced cell, c, to g, various forms of human muscular fibre.

Mode of Development.—There is no difference in the early stage of development between the striated and nonstriated varieties of muscular tissue, both being developed from cells; but whilst the striated variety goes on to complete development into fibrillæ, the nonstriated retains permanently its cellular condition. The cellular elements are elongated and applied end to end, being held together by connective tissue, and in this way they encircle the organ into the formation of which they enter, or are arranged longitudinally or obliquely. The striated fibre is not formed as

formerly supposed by Schwann, directly from the arrangement and fusion of the cells in a linear manner (except probably the fibres of the heart), but by the arrangement and fibrillation of the protoplasm or intercellular substance under the influence of the cells. The cells appear to increase greatly in length, the nuclei increase in number, and the protoplasm and intercellular substance become transformed into the sarcous elements, etc. The fibre becomes transversely and longitudially striated, and increases in size by fresh additions of protoplasm upon the outside. The remains of the nuclei, surrounded by granular protoplasm (the muscle corpuscle) may be seen on the outside and within the sarcolemma, on the addition of a little acetic acid.

ATTACHMENT OF TENDONS.—Every muscle is attached at its extremity by means of connective tissue, which constitutes the tendon. The extremity of each muscular fibre, whether rounded, pointed, or irregular, is covered by sarcolemma, and is received into a corresponding cavity in the tendinous bundle to which it is firmly connected, by means of a cement substance. This union is so firm, that rupture of the tendon or muscle will take place before separation at this point. It may be separated for microscopical examination, by means of a solution of potash.

Fig. 37.



Extremity of muscular fibre, showing the attachment of the tendon.

CHEMICAL CONSTITUENTS.—Muscular tissue consists as follows in 100 parts:

Water	76.50.
Myosine, Albuminous substances and Hemoglobine	18.20.
Lactic acid	1.00.
Gelatine	1.50.
Creatine, Extractive, and Fatty Matter and Salts	2.80.
	100.00.

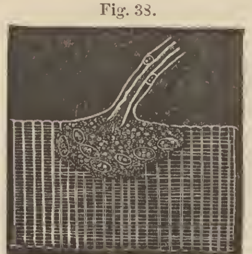
It swells out on the addition of acetic acid, and is partially dissolved. It is soluble in hydrochloric acid, and is

precipitated by ferrocyanide of iron. Muscular tissues is sometimes changed into a substance called *adipocere.* (See oils and fats.)

VASCULAR SUPPLY.—The arteries intended for the supply of the muscle pierce the sheath, and divide and subdivide, giving off small branches which pass between the bundles of which it is composed, until the ultimate twigs insinuate themselves between the primitive fasciculi or fibres, and terminate in the capillaries. Some of these, the longitudinal, course along the fibres, lying in the intervals between them, and others pass transversely across them. The length of the longitudinal capillaries is about $\frac{1}{20}$ of an inch (1.2 mm) the transverse vary according to the size of the fibres. The fibrillæ are, therefore, supplied by imbibition through the sarcolemma.

NERVOUS SUPPLY.—The nerve fibres are distributed similarly to the arteries, until the filaments reach the fasciculi or fibres. They then form a series of loops, which either return to the same trunk, or join an adjacent one. It is stated by some observers, that the nerve fibres pierce the sarcolemma. As they pierce the fibre, their covering becomes continuous with the sarcolemma, and the axis cylinder or essential portion of the nerves pass into the interior and are distributed among the fibrillæ, and terminate either in free extremities, loops, or nerve buds (as they are called).

Fig. 33.



Termination of a nerve fibre by a motor end plate in muscuar fibre, (Longet).

According to other observers the nerve fibres as they approach the sarcolemma form expansions, called terminal, or motor end plates. The sheath of the nerve spreads out and blends with the sarcolemma, the white substance of Schwann terminates abruptly, and the axis cylinder spreads out beneath the sarcolemma on the surface of the fibrillæ, forming an oval

plate, from $\frac{1}{500}$ to $\frac{1}{1000}$ of an inch (50 to 25 mmm) in diameter. (Fig. 38).

Properties of Muscular Tissue.—The distinguishing characteristic of muscular tissue is its property of *contractility, irritability* or *tonicity.* Some have endeavoured to draw a distinction between these terms ; but, after all, it is a distinction without a difference. The term tonicity however, may be understood to express that *insensible* and almost constant contraction by which opposing muscles balance each other in a state of rest—a state of passive contraction. The primitive fibrilla is the proper contractile tissue of the muscle. Still, it is a disputed point as to whether or not it possesses this property in itself, some maintaining that nerve is necessary to charge it with contractility ; others that nerve is only necessary to call it into action, and that this property is inherent in the tissue itself. Contraction is caused by a change in the shape of the sârcous elements; they become shorter and thicker. This change travels rapidly from one end of the *fibrilla* to the other, and the muscle is thus very much shortened. Some vegetable structures possess an analogous property, as *e. g.* the mimosa or sensitive plant, and venus' fly-trap (Dionœa). If touched ever so slightly, the irritation causes a change in the shape of the cells, followed by a change in the shape or position of the whole leaf, in consequence of the change travelling from one cell to another. The property, therefore, of contractility is inherent in the muscular fibrilla itself, and may be called into action by various kinds of stimuli, as by nervous influence, by pinching or pricking the tissue, by the action of an acid or an alkali, or by galvanism. The effect of the application of any of these stimuli, varies according to the kind of muscular tissue to which it is applied. If a portion of striated muscle be irritated, those fibres which are touched will contract, and those only, the motion not being communicated to any other, and the contracted part soon becomes relaxed—the spasm is clonic.

If, on the other hand, a portion of nonstriated muscle be irritated, as the alimentary canal, the contraction takes place more slowly, the spasm is long continued, or tonic, and the movement is communicated to other fibre-cells, until a considerable part of the canal is affected. The muscular fibre is shortened and thickened during contraction, and sometimes thrown into a zigzag shape, and some observers, mistaking the effect for the cause, concluded that the zigzags occasioned the shortening. Contractility continues for a short time after death. This may be demonstrated, by applying to the muscular tissue any of the above-mentioned stimuli which are known to affect it during life. The duration of this property after death, varies in different animals. In birds, only a few minutes after death; in quadrupeds much longer; while in reptiles it remains for many hours, owing to the nutritive changes being more sluggish in these than in warm-bloods, and the sarcous elements being slowly formed and sluggish in their action, are long-lived.

If irritation be continued, the contractility or irritability of the muscle is soon exhausted. The circulation of arterial or oxygenated blood is not only necessary for the purposes of nutrition, but also to the continuance of contractility. The muscles will therefore preserve their contractility after death, and the action of the heart itself will continue for a long time, if oxygenated blood be injected into the veins or if the circulation be kept up by artificial respiration. If the blood be charged with carbonic acid, or chloroform, ether, sulphocyanide of potassium, or a narcotic poison, as opium, etc., the contractility of the muscles is speedily destroyed.

Every act of contraction involves the death of a certain amount of muscular tissue, and prolonged exertion causes fatigue, which is an evidence of an impaired condition. Rest is necessary to recovery, and recovery is due to the nutritive process; hence the more a muscle is used, provided it receives a sufficient amount of rest and nutrition,

the more vigorous and bulky does it become; as *e. g.*, the arm of the smith, and the legs of the rope-walker. On the other hand, disease, as paralysis, or sedentary habits, cause them to become flabby and atrophied, but this may be remedied by exercise, and the use of friction and galvanism. In some constitutions they are liable to fatty degeneration.

Muscular contraction produces a *sound* resembling the distant rumbling of carriage wheels. This is caused by the movements of the fibres upon each other. For example, the sound caused by the contraction of the masseter and temporal muscles may be distinctly heard in the stillness of the night, by placing the side of the face and ear on the pillow, and clenching the teeth firmly together.

There is also an *elevation of temperature* of from 1° to 2° F. This depends partly on the chemical changes which take place in the muscle, as a result of its action, and partly upon the friction consequent on the movements of the fibres upon each other.

Muscular tissue is also said to possess a certain amount of *elasticity*. This is exceedingly small, and is due in great measure to the elasticity of the sarcolemma and the elastic tissue associated with muscle. It is shown by suspending vertically a small weight to a portion of fresh muscle; it elongates with the weight and recovers itself when it is removed.

Rigor Mortis.—This is the stiffening of the muscles which takes place after death, and is due to the coagulation of myosin. This condition is rarely absent; but it may be very slight, and continue only a short time. Sometimes it comes on within 15 or 20 minutes after death, as in typhus fever. It commonly takes place within 7 or 8 hours after death; but in some cases it may be deferred for 20 or 30 hours. It continues for 24 or 36 hours; but it may pass off much more rapidly, or be continued for several days. This rigor mortis is a sort of tonic contraction of the muscles, and in some cases it may be very violent—as after

6

death from cholera and yellow fever—and has given rise to many absurd superstitions among the uninitiated. It begins in the neck and lower jaw first, next the upper extremities, and extends from above downwards until it reaches the lower limbs. It is most remarkably manifested in the nonstriated muscular tissue, as in the arteries and alimentary canal. In consequence of this contraction, the bowels are not unfrequently moved after death; the arteries are found empty, and so contracted that they cannot be injected until the rigidity passes off. When the rigor mortis subsides, decomposition of the muscular tissue begins; hence we may regard it as the last act of life, and in this respect it corresponds to the coagulation of the blood, when drawn from the body. The same causes that interfere with the coagulation of the blood after death, interfere, also, with the rigor mortis of the muscles, as in animals hunted to death, or killed by lightning, in which both coagulation and rigor mortis are imperfect.

Action of Muscles.—In the action of most muscles, and especially those of the extremities, examples of the three orders of *levers* are afforded.

In the *first order* of levers the power is at one end, the weight at the other, and the fulcrum between the two.

In the *second order*, the power is at one end, the fulcrum at the other, and the weight between the two.

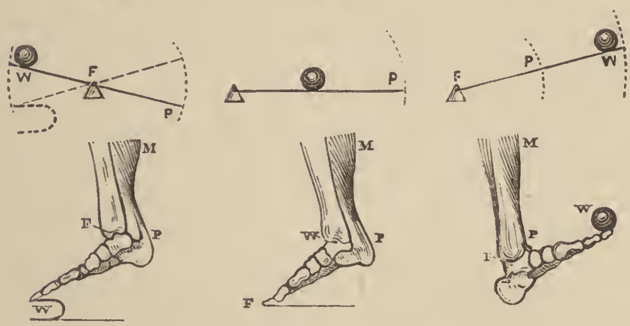
In the *third order*, the fulcrum is at one end, the weight at the other, and the power between the two.

The first order of levers, although the most powerful, is that least used in the animal economy, as its use is less productive of extensive motion. The action of the gastrocnemius muscle affords an example of this order, as when the foot is raised from the ground, and extended to raise the os calcis and depress the toes: here the moving power is the gastrocnemius attached to the os calcis, the weight is the anterior part of the foot, and the fulcrum is the ankle joint.

The same muscle affords an example of the second order

of levers, as when the foot is placed on the ground and the body raised by the action of the muscle; here the moving power is the gastrocnemius, the fulcrum the anterior part of the foot resting on the ground, and the weight or resistance the body resting on the ankle joint.

Fig. 39. Fig. 40. Fig. 41.



The upper three figures represent the three kinds of levers; the first illustrating the mode of action in two directions. The lower figures represent the foot when it takes the character of each kind of lever. F, fulcrum; P, power; W, weight or resistance; M, muscle, affording the power.

The ankle joint also affords an example of the third order of levers, as when the foot is raised from the ground and flexed on the ankle joint; here the moving power is the tibialis anticus and peroneus tertius, the fulcrum is the ankle joint, and the weight the anterior part of the foot.

The biceps of the arm also affords a good example of the third order, as when a ball or weight is placed in the hand; here the moving power is the biceps inserted into the tuberosity of the radius, the fulcrum is the elbow joint, and the weight is in the hand. In this position, power is sacrificed to extent of motion, as in raising the hand and weight these pass through the arc of a circle of considerable dimensions, while the extent of motion at the insertion of the power is extremely limited. This is still more obvious when we hold a rod in the hand, as a fishing-rod or whip, the extreme end of which is made to pass through a space of con siderable magnitude compared with that of the part where

the power is applied. The great advantage derived from this disposition of levers in the human body, whereby motion is gained at the expense of power, is seen in the various acts of walking, running, leaping, etc.

Locomotion.—In the act of walking nearly every muscle in the body is called into action, either in the movement of the limbs or in the maintenance of the body in the erect position. Two main kinds of leverage are employed in walking, one kind chiefly produced by the muscles of the calf which raise the heel, and with it the weight of the body which is *pushed* forward, and would fall prostrate, but for the other kind of leverage by which the opposite leg is *pulled* or planted in front of the body to support it. The advance of the opposite leg is effected partly by swinging, but chiefly by muscular action. The muscles concerned are those of the thigh, the rectus, psoas and iliacus, which act in front; the hamstring muscles which slightly bend the knee, and those on the front of the leg, as the tibialis anticus, extensor longus digitorum, extensor longus pollicis and peroneus tertius which raise the foot and toes, and prevent them catching on the ground. When this foot, which we will suppose to be the *right*, has reached the ground, the action of the muscles of the left leg has not ceased, but continues to raise the heel and throw the body still more forward, until the weight is supported by the right leg, when the left in its turn swings around and is planted in front of the body. The two actions it will be seen, therefore, are taking place at the same time, and are assisting each other.

At the same time that the above movements are in progress, the body is being supported in the erect posture and balanced on each leg alternately. This is done by a slight rotation of the pelvis on the head of each femur alternately, so that the centre of gravity of the body shall fall over the foot of that side. This occasions a slight "rocking movement" which is more noticeable in females than males owing to the greater width of pelvis of the former. This rocking

movement may, however, be lessened, and made more graceful by a compensatory outward movement at the hip, and hence some may become more graceful in their walk than others. Running, and leaping or jumping are modifications of the act of walking.

In regard to the *source of muscular force*, it has long been observed that in active muscular exercise, there is an increase in the urea excreted by the kidneys, and it was supposed that this increase of urea was in exact proportion to the amount of muscular exercise. The latter has been found not to be the case; the increase in urea is only very slight, and the waste of muscle cannot be expressed by its increased excretion; neither is the substance of muscle wasted in proportion to the work it performs. There is also no evidence that nitrogenous are superior to non-nitrogenous foods as a source of muscular power; both may afford the requisite conditions for muscular action.

CHAPTER IV.

MEMBRANOUS EXPANSIONS.

These are the *serous and synovial*, *mucous* and *integument.* The serous and synovial membranes, anatomically speaking, form shut sacs, with the exception of the peritoneum in the female, which communicates with the uterus through the Fallopian tubes. The mucous membrane lines cavities which communicate with the external surface, and is continuous with the integument. The integument covers the exterior of the body, and serves not only as a means of protection, but also as an organ of sensation. The mucous membrane and integument are convertible membranes.

STRUCTURE.—The structure of these membranes is very nearly the same in each instance. It consists of a basement membrane, lined by epithelial cells on the free surface, and presents vessels, nerves, and lymphatics, imbedded in areolar tissue which connects it with the subjacent parts (Fig. 42). They therefore consist of *three parts*—*basement membrane*, with *epithelial cells* on one side, and *blood-vessels*, *nerves* and *lymphatics*, imbedded in areolar tissue, on the other.

Fig. 42.

Plan of a membranous expansion ; a, epithelium , b, basement membrane ; c, vessels, nerves and lymphatics imbedded in areolar tissue.

1st. BASEMENT MEMBRANE.—The different varieties of basement membrane have been already described in Chapter II. Its function is to support the cells, and probably influence their development; to limit osmosis of the nutrient fluid from the subjacent capillaries, and modify it in its passage.

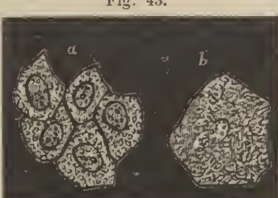
2nd. EPITHELIUM.—The layer of cells which line the free

surface of the membranous expansions, is called *epithelium.* Those which line the serous and synovial membranes and the vascular system are sometimes called *endothelium,* and the stratified epithelium of the skin is called *epidermis.* The epithelial cells can be brought beautifully into view by staining with nitrate of silver.

There are two principal varieties of epithelium, viz: 1st. *Tesselated, pavement, squamous, laminated* or *scaly.* 2nd. *Columnar* or *cylindrical.* In the serous, synovial, and mucous membranes there is generally a single layer of cells, with a quantity of granular matter and a layer of partially developed cells lying on the basement membrane; but in the integument there are several; the outer being flattened, scaly, and hardened by secondary deposit. The cells which line the serous, synovial and mucous membranes, secrete a fluid which is intended to lubricate the surface, to prevent the ill effects of friction, and to give ease to the gliding movements of the parts over each other. This fluid is formed as a result of the growth, maturity, and decay of the cells.

1st. TESSELATED, PAVEMENT, SQUAMOUS, OR SCALY EPITHELIUM.—The cells of this variety are flattened and polygonal in shape, and vary in size from $\frac{1}{500}$ to $\frac{1}{2500}$ of an inch (50 to 10 mmm) in diameter. Each cell contains a nucleus, nucleolus, and granular matter. They are, in general, not very active, and are therefore long-lived. In health, they secrete only a limited quantity of fluid. Those which line the synovial membranes, mucous membrane of the mouth, and parts of the body in which a greater supply of fluid is requisite, are somewhat rounded in shape and much more active. Tesselated or pavement epithelium lines all the serous and synovial membranes, the mucous membrane of the mouth, lower part of the pharynx, œsophagus, upper part of the larynx,

Fig. 43.



Tesselated epithelium; a, epithelium of the peritoneum × 400; b, epithelial cell of the mouth × 260 (Henle).

intercellular passages (so called), and air cells, lining membrane of the ventricles of the brain, tympanum, anterior and posterior chambers of the eye, conjunctiva and canaliculi, arteries, veins, and lymphatics, lower part of the vagina, bladder, and urinary passages, vesiculæ seminales, and vas deferens.

Those cells which line the bladder and urinary passages are somewhat spheroidal in shape, and would seem to be an intermediate variety.

2nd. COLUMNAR OR CYLINDRICAL EPITHELIUM.— This variety is cylindrical in shape, as the name indicates, and placed side by side, one extremity of the cell resting on the basement membrane, and the other forming the free surface. They vary in size from $\frac{1}{2500}$ to $\frac{1}{3500}$ of an inch (10 to 7.1 mmm.) in thickness, and from $\frac{1}{600}$ to $\frac{1}{900}$ of an inch (42 to 28 mmm.) in length. Each cell contains a nucleus and nucleolus. In some parts, as in the gastro-intestinal canal, there appears to be a double layer of cells; this depends on their rapid development in these parts, the lower layer being the new cells which are rising up to take the place of the old. These cells not only line the free surface of the membrane, but also dip into the follicles, at the bottom of which they become rounded or *glandular*. This is owing to their greater activity in the latter situation. In some instances their free extremities are club-shaped, in order to comport with their position, as when they stand on the angles formed by the dipping of the follicles.

Fig. 44.

Columnar epithelium; c, columnar epithelium of intestine; d, columnar ciliated epithelium of the nose.

This form of epithelium is found in the alimentary canal, commencing at the cardiac orifice of the stomach, in the ducts which communicate with it, the gall bladder, nose, nasal ducts and lachrymal sacs, frontal sinuses and antra, posterior surface of the palate, upper part of the pharynx,

Eustachian tubes, larynx—below the superior vocal cords—trachea and bronchi, upper part of the vagina, uterus, and Fallopian tubes.

Fig. 45.

Columnar epithelium of small intestine; a, Becher or goblet cells; b, ordinary cells.

Placed here and there at variable distances among the ordinary columnar cells are peculiar oval cells known as Becher or *goblet-cells* (Fig. 45, a.) These are regarded by some as the commencement of the absorbent system; by others as mere shells of epithelial cells which have become emptied of their contents by manipulation, or as mucous secreting cells.

Cilia.—Both varieties of epithelial cells occasionally present a number of minute, conical-shaped filaments or prolongations attached to their free extremities or surfaces, termed *cilia* (Fig. 44, d). They are attached by their bases to the cells, their free extremities being tapered, and they vary in length from $\frac{1}{5000}$ to $\frac{1}{1000}$ of an inch, (5 to 6 mmm.) From five to thirteen may be seen attached to each cell. The cilia may be considered as prolongations of the cell itself. They are not seen in the early stage of development of the cell, but make their appearance as it arrives at maturity. They are in continual motion; each filament appears to bend from its root to its point and return to its original state, so as to resemble the waving of a wheat field in a gentle breeze. This motion is independent both of the will and the life of the animal, as it is seen to continue after death. Epithelial cells of the nose may be seen to float about in water by the agency of their cilia, several hours after they have been removed from the mucous surface; and the motion of the cilia has also been observed in the body of the tortoise fifteen days after death. Ciliary motion continues in animals killed by prussic acid, narcotic or other poisons, and electricity; but is destroyed by chloroform, carbonic acid, mineral acids and strong alkalies.

The object of the ciliary motion is to propel fluids over the surface, in the direction which the secretion is destined to take, whether external or internal, the movement being generally towards the outlets. In fishes, the external surface of the gills is covered with cilia, which serve to propel the water, and bring fresh portions in contact, for the purpose of aërating the blood. In many of the lower animals, they serve not only to produce currents for respiration, but also to draw into the mouth minute particles which serve as food.

The motion of the cilia is due to the vitality of the cells from which they grow, or the vital contractility of the tissue of the cilia themselves, and not to the presence of a kind of delicate muscular tissue, or to nervous force, as some have suggested. It has already been shown, in the preceding chapter, that the motion of muscular tissue is due to a change in the shape of the sarcous elements. Now, in the same way, the motion of the cilia may be produced by a change in the shape of the cells to which they belong, so that by an alternate contraction and relaxation of the cell the cilia would be made to wave as they are seen to do.

The epithelial cells are developed from the protoplasm supplied by the vascular layer, beneath the basement membrane.

Ciliated epithelium of the tesselated or squamous variety is found in the lining membrane of the ventricles of the brain, tympanum, intercellular passages (so called), and in the air cells.

Ciliated epithelium of the columnar variety is found in the cavity of the nose (except the roof), nasal ducts, lachrymal sacs, frontal sinuses, maxillary antra, Eustachian tubes, posterior surface of the palate, upper part of the pharynx, (extending as low down as the floor of the nares), larynx below the superior vocal cords, and the anterior part above, trachea and bronchi, upper part of the vagina, in the uterus, and Fallopian tubes.

SEROUS MEMBRANES.

The serous membranes are the arachnoid, pleura, pericardium, peritoneum, tunica vaginalis, and the lining membrane of arteries, veins, and lymphatics. Each membrane, respectively, lines the cavity to which it belongs, being attached to the wall by means of areolar tissue. This is called the *parietal layer.* It is then reflected upon the contained organ forming the *visceral layer.* The free surface is lined by tesselated or squamous epithelium, sometimes called endothelium, which in health secretes a limited quantity of fluid for the purpose of moistening the surface, the process of secretion and absorption being exactly counterbalanced. The normal quantity of serous fluid in the various cavities is as follows; in the pericardium one to two fluid drachms; in the peritoneum one to three ounces; in the pleural sac two to four fluid drachms. If the secretion be morbidly increased, or the process of absorption diminished it is retained in the cavity, and gives rise to dropsies which receive different names in different parts of the body; in the cavity of the arachnoid, hydrocephalus; in the pleura, hydrothorax; in the pericardium, hydro-pericardium; in the peritoneum ascites; in the tunica vaginalis, hydrocele. The secretion is called serous fluid, and is similar to the serum of the blood. It has an alkaline reaction, and consists of water, albumen and salts. The quantity of albumen varies in different parts, depending on the activity of the part, the degree of motion and the amount of friction to be overcome. In the serous fluid of the pleura there are 2.85 parts in a hundred; in the peritoneum, 1.13 parts; in the arachnoid, .6 to .8; in the subcutaneous areolar tissue, .36.

The serous membranes are looked upon by some, as large sacs or cavities, which communicate by stomata or pores, with the lymphatic vessels (Klein.) These apertures, which are about $\frac{1}{2500}$ of an inch (10 mmm) in diameter, may be seen between the epithelium. Milk and colored fluids have

been observed to pass through them into the lymphatic system. Short lateral passages of the lymphatics are also found to open into these apertures. There is also a considerable quantity of adenoid tissue imbedded in, or forming the walls of the serous membranes.

SYNOVIAL MEMBRANES.

The synovial membranes are placed between the articular surfaces of the bones. In the fœtus they are prolonged over the articular cartilage ; but in the adult they cover merely the margin to the extent of a line or two, and are then reflected on the inner surface of the ligaments, to which they are attached by areolar tissue. In some instances they send fringe-like prolongations into the interior of the joints, as for example, the (so called) alar ligaments of the knee joint. They also form sheaths for the tendons of muscles. The free surface of the synovial membrane is smooth and moist, being lined by a layer of tesselated or squamous epithelium, which secretes the synovia, for the purpose of lubricating the joint, and preventing the ill effects of friction. If the secretion be morbidly excessive, the result would be *hydrops articuli.*

SYNOVIA is a transparent, viscid, oily-looking fluid, and resembles the white of an egg, hence its name (συν, cum, ωον, ovum.) It has an alkaline reaction, and contains water, albumen or synovine, and salts. It contains more albumen than serous fluid, more being necessary on account of the greater amount of motion in the joints.

BURSÆ.—A reflection of synovial membrane in the form of a closed sac, is found beneath some of the tendons where they glide over bony surfaces. This is called a *synovial bursa.* When they are situated near a joint they sometimes communicate with its synovial cavity. They line the canal or groove and are reflected around the tendon forming its sheath, at the same time excluding it from the synovial

cavity. There is another variety of bursæ situated between the integument and bony prominences, as between the integument and patella, olecranon, etc. These are called *bursæ mucosæ*, and are nothing more or less than an enlarged mesh in the areolar tissue, surrounded by condensed fibres, and presenting a partial or incomplete secreting surface.

Synovial membranes are more readily reproduced than serous membranes. It is doubtful whether the latter are reproduced at all or not; but new joints are formed and lined by synovial membrane, as is seen in old-standing dislocations of the hip, etc. Serous membranes, when inflamed pour out a plastic substance, which has a tendency to organize and form bands; but in inflammation of synovial membranes there is a tendency to the formation of pus.

STRUCTURE OF SEROUS AND SYNOVIAL MEMBRANES.—They are very nearly alike. On their free surface is a layer of epithelium, of a polygonal shape, and more or less transparent. This rests on the basement membrane, which is also nearly transparent, and very thin. Beneath the basement membrane is a layer of areolar tissue, in which are imbedded the vessels, nerves and lymphatics; this constitutes the chief thickness of the membrane, and gives it strength and elasticity. The areolar tissue is more condensed beneath the basement membrane, and becomes more lax near the subjacent tissue. The vessels are arranged in a plexiform manner, running parallel with the basement membrane. In parts of the body where there is much motion, and a greater supply of blood is necessary, as beneath the pleura and the synovial membranes, the vessels are tortuous.

MUCOUS MEMBRANES.

These resemble the serous and synovial, in lining cavities, but they are not shut sacs. They line the interior of the alimentary canal from the mouth to the anus, the ducts,

and interior of glands which communicate with it; the nose and the passages which open into it, the larynx, trachea, bronchi, and air cells, bladder and urinary passages, vagina, uterus and Fallopian tubes. The free surface of the mucous membrane is lined by a layer of epithelium, generally of the columnar variety; the exceptions are the mouth, upper part of the larynx, lower part of the pharynx, œsophagus, tympanum, intercellular passages and air cells, lower part of the vagina, bladder and urinary passages. The cells secrete a fluid called *mucus*, which is intended to lubricate the surface, and protect it from the contact of air, and any irritating substance to which it may be exposed.

Mucus is a transparent, viscid, tenacious, semi-fluid substance, insoluble in water, but may be readily dissolved by any alkali. It is coagulated by weak mineral acids, acetic acid, and strong alcohol. A substance resembling mucus may be obtained from any inflammatory exudation, or even from pus, by treating it with liquor potassa and agitating it. Any irritation to the mucous surface, from whatever cause, will increase the secretion of mucus, as for example the use of snuff, etc. It consists of about 93 to 94 parts fluid, and from 6 to 7 parts solid matter. The organic matter is termed *Mucine* or *Mucosine.* Mucus of the nose consists of ;—(Robin)

Water	93.3
Mucine	5.4
Fatty and Extractive Matter	.3
Salts	1.
	100.00

The salts consist of sodium and potassium chloride .6 parts; sodium and potassium phosphates, sulphates, and carbonates, and lime phosphate .4. The part of the body from which the mucus is obtained may be determined by the form of epithelium present in it, the result of desquamation, It has an alkaline reaction except in the vagina where it is acid.

STRUCTURE.—The mucous membrane, like the serous

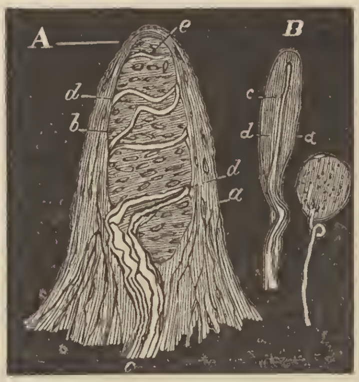
and synovial, consists essentially of three parts; the *epithelium*—the *basement membrane*—and the *areolar tissue*, in which the vessels, nerves and lymphatics are imbedded, and which connects it with the subjacent parts. The latter gives the membrane its thickness, and is made up of white fibrous, and yellow elastic tissue, vessels, etc. In the mucous membrane of the erectile tissues, as in the organs of generation, some nucleated, fusiform, muscular fibre-cells are seen imbedded in the areolar tissue. The epithelium not only covers the free surface of the membrane, but also dips down to line the follicles, ducts, etc. It also covers the surface of the villi and valvulæ conniventes. The relative amount of vessels, nerves, and lymphatics, depends upon the activity of the parts; the vessels are also more tortuous where a large supply of mucus is requisite Some parts of the mucous surface are not so sensitive as others; for example, the passage of food is not felt in the œsophagus, stomach, and intestines until the fæcal matter reaches the rectum, when a sensation is felt demanding its discharge. This depends on its nervous supply—the rectum being largely supplied by spinal nerves, while the rest of the intestines, stomach, and œsophagus, are more directly under the influence of the sympathetic system. Mucous surfaces are not disposed to form adhesions in inflammation, owing to the presence of the epithelium and mucus. These change the character of the plastic material, and cause it to degenerate into pus; but if the epithelium be entirely removed a partial organization takes place, as may be seen in the casts of the alimentary canal in dysentery, when not of a very low type.

APPENDAGES OF THE MUCOUS MEMBRANE.

In most parts of the body the mucous membrane is provided with papillæ, and follicles, or glands. In the alimentary canal, the mucous membrane is thrown into folds called valvulæ conniventes. There are also velvet-like projections called villi. These are termed appendages.

PAPILLÆ.—Of these there are two kinds, *spongy* or *vascular*, as found in the tongue, etc., and *rough* or *horny*, as found in the integuments of the palms of the hands and soles of the feet. In the integument they are the organs of touch or *tactile organs;* in the tongue, the organs of the special sense of *taste*, and also of touch; the former will be described with the integument.

Fig. 46.



A, Cutaneous papilla of the hand; a, cortica layer with cells and elastic fibres; b, tactile corpuscle; c, nerve fibres (Kolliker).

A papilla is a slight elevation of the surface of the membrane of which it forms a part, consisting of the basement membrane covered by one or more layers of epithelium, and containing within a reticula of capillaries, nerves forming loops, lymphatics, and in some instances nonstriated muscular fibre-cells, the latter causing it to contract and become prominent when any irritation is applied. Some of the papillæ are cleft, as for example, those in the back part of the dorsum of the tongue and in the hands.

The papillæ of the tongue may be divided into *simple* and *compound.* The simple papillæ are dispersed over the surface of the tongue among the compound forms. The compound are the *circumvallate, fungiform,* and *filiform,* and are visible to the naked eye.

The *circumvallate* papillæ are of a large size, and vary in number from eight to ten. They are situated on the dorsum of the tongue, near its base, and consist of a row on each side, which runs obliquely backwards and inwards, to terminate in one large papilla situated in the median line, called the *foramen cæcum.* The two lines resemble the letter V inverted. Each papilla consists of a circular flat-

tened projection of the mucous membrane, from $\frac{1}{25}$ to $\frac{1}{12}$ of an inch (1 to 2 mm.) in diameter, surrounded by a narrow circular fissure, this fissure being again surrounded by a narrow circular elevation of the mucous membrane. The whole surface of these papillæ is studded with numerous smaller or secondary papillæ, and invested with epithelium, the deep layer being rounded, the superficial, scaly.

Fig. 47.

The tongue with its papillæ and nerves, (Herschfeld).

The *fungiform* papillæ are scattered irregularly among the filiform papillæ on the dorsum of the tongue, but chiefly at the sides and apex. They vary from $\frac{1}{25}$ to $\frac{1}{35}$ of an inch (1 to .7 mm.) in diameter, generally narrower at the base than the summit, and studded with numerous smaller papillæ, like the preceding variety. They have a reddish color, owing to the thinness of the epithelial covering.

The *filiform papillæ* cover the anterior two-thirds of the tongue. They are conical in shape, and vary in thickness from $\frac{1}{50}$ to $\frac{1}{70}$ of an inch (.5 to .35 mm.) and are about $\frac{1}{10}$ of an inch (2.5 mm.) in length. They are pale in color, owing to the density of the epithelium, and are also covered with

numerous secondary papillæ, some of which enclose minute hairs from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch (12.5 to 8.3 mmm.) in thickness and about $\frac{1}{10}$ of a line in length. Besides the papillæ, the mucous membrane of the tongue is provided with a number of follicles and glands. There are also special organs of taste called taste-buds. (See special senses).

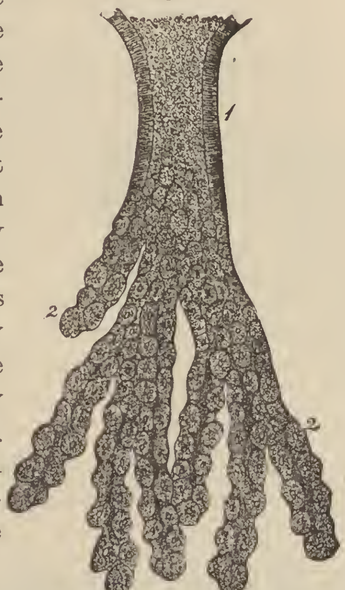
FOLLICLES.—These are found in nearly all mucous membranes. Those of the tongue are called lingual follicles; those of the stomach, gastric follicles; those of the intestines, simple follicles, or Lieberkühn's follicles; those of the uterus, uterine follicles, etc. In structure they are essentially the same. They consist of minute tubular depressions of the mucous membrane, or inversions, like the finger of a glove, arranged perpendicularly to the surface, upon which they open by minute apertures. Their walls consist of a basement membrane lined by epithelium, which is generally columnar on the sides and round in the bottom, and covered externally by the vessels, nerves, etc. In some instances, as in the stomach near the pylorus, the follicles subdivide into from two to four tubular branches, or cæcal pouches, and are sometimes convoluted (Fig. 48.) In other instances they are arranged like a cluster of grapes on the stem, and are termed racemose as in the mucous membrane of the pharynx, trachea, etc.

The *mucous membrane of the stomach* presents a peculiar honey-combed appearance, consisting of shallow polygonal pits or depressions, from $\frac{1}{100}$ to $\frac{1}{350}$ of an inch (250 to 71 mmm.) in diameter, separated by slightly elevated ridges. In the bottom of these depressions are seen the openings of minute tubes, the gastric follicles. These are divided into two varieties, *mucous follicles*, or those that secrete mucus, and *gastric or peptic follicles*, or those that secrete the gastric juice. These two varieties differ only in the character of the epithelium which lines them. The mucous follicles are lined by columnar epithelium on the sides and rounded in the bottom. In the peptic follicles, the deep

part of each tube is filled with large, granular spheroidal cells, and rounded epithelium, the upper part being lined by columnar epithelium (Fig. 48).

The *follicles of Lieberkühn* are found throughout the whole course of the small and large intestines. They are very numerous, and consist of simple involutions of the basement membrane, carrying with them the layer of epithelium. They are absent only in the space occupied by Brunner's glands and the centre of the solitary glands. In the latter instance they surround the solitary gland in the form of a ring. (Fig. 49.) These follicles open between the villi, are cylindrical in shape, and secrete the intestinal juice proper.

Fig. 48.



Compound peptic follicle. 1, excretory duct lined by columnar epithelium; 2, branched terminations filled with large, granular spheroidal cells, and rounded epithelium.

In some parts of the body the mucous membrane is thrown into folds or *rugæ.* Some of these are of a *temporary* nature, such as are seen in the empty state of all hollow organs, as the stomach, bladder, etc., and others are *permanent* as the *valvulæ conniventes,* ileo-cæcal valves, folds of the rectum, etc.

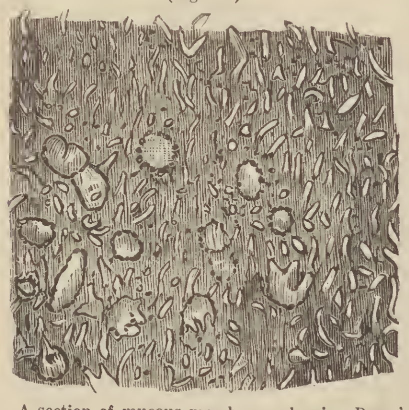
Valvulæ Conniventes.—The valvulæ conniventes are reduplications or foldings of the mucous membrane, containing between them vessels, nerves, and lacteals or lymphatics imbedded in areolar tissue. They pass transversely around the cylinder of the intestine for about $\frac{3}{4}$ or $\frac{5}{6}$ of its circumference, being about two inches in length, and from $\frac{1}{3}$ to $\frac{2}{3}$ of an inch (8 to 16 mm.) in depth at the centre. They begin at the hepatic flexure of the duodenum, and in-

crease in size and frequency, until they pass below the entrance of the ductus communis choledochus. They then diminish gradually towards the lower part of the ileum, where they entirely disappear. They are studded with villi and covered with a layer of epithelium. The valvulæ conniventes retard the passage of food along the intestines, and increase the extent of surface for absorption.

The permanent folds of the large intestines are the sacculi, the ileo-cæcal valve, and the folds of the rectum. The latter are three or four in number; the first is near the upper part of the rectum, on the right side; the second is on the left, opposite the middle of the sacrum; the third, which is the largest and most persistent, is in front, opposite the base of the bladder. When the fourth is present, it is situated behind, about half an inch above the anus. Their function is to support and gently retard the passage of fæcal matter towards the anus.

VILLI.—The villi are found throughout the whole extent of the small intestines, from the pylorus to the ileo-cæcal valve, covering the surface of the valves next the ileum, and terminating at the free margin, being entirely absent on the cæcal surface. They are minute, highly vascular prolongations, or eversions of the mucous membrane, and give to its surface a velvety appearance (Fig. 49). They are conical or filiform in shape, and vary in length from $\frac{1}{25}$ to $\frac{1}{60}$ of an inch, (1 to .4 mm.) and from $\frac{1}{60}$ of an inch in thickness at the base, to $\frac{1}{150}$ of an inch (.4 to .16 mm.) near the summit. The villi are

(Fig. 49.)



A section of mucous membrane, showing Peyer's glands, surrounded by the openings of Lieberkühn's follicles and covered with villi.

largest and most numerous in the duodenum and jejunum, there being about fifty to ninety in a square line ; but they become sparser in the ileum. The total number for the whole intestine is upwards of ten millions.

STRUCTURE.—Each villus consists of a basement membrane covered with a layer of columnar epithelium, externally, and contains in its interior a network of capillaries, nerves, and the commencement of the lacteal, with nucleated cells and fat globules in their interstices, and held together by areolar tissue. It also contains some fusiform muscular fibre-cells, which probably assist in the propulsion of the chyle after it enters the lacteals, (see chapter on absorption.) The presence of nerves has not been satisfactorily demonstrated, but they are believed to exist. According to some observers there are to be found here and there between the ordinary columnar cells, oval shaped cells called *cup* or *goblet* cells (Fig. 45 a.) These have been regarded as the true commencement of the absorbent system.

(Fig. 50.)

An intestinal villus ; *a*, the cylindrical epithelium ; *b*, the capillary network ; *c*, smooth muscular fibre ; *d*, lacteal.

DUODENAL OR "BRUNNER'S" GLANDS.—These are limited to the duodenum and commencement of the jejunum. They are small, ovoid, lobulated bodies, about $\frac{1}{10}$ of an inch, (2.5 mm.) in diameter, imbedded in the submucous areolar tissue, and open upon the surface of the mucous membrane by minute excretory ducts. These glands are most numerous near the pylorus, and diminish from above downwards. In structure, function, and in the character of their secretion, they resemble the pancreas.

SOLITARY GLANDS. "PEYER'S" GLANDS.—These are small,

round, whitish bodies, from one-fourth of a line to a line (2 to .5 mm.) in diameter, consisting of closed vesicles having no apparent excretory duct, and made up of adenoid tissue, the meshes of which contain a whitish secretion consisting of nucleated cells or lymph-corpuscles, nuclei and granular matter (Fig. 49). Each follicle is surrounded by a lymphatic vessel, and a minute vascular net work; from the latter, capillary vessels pass into the interior and return in loops. In the lower part of the small intestines they are aggregated together in circular or oval patches, from twenty to thirty in number, called *Peyer's patches* or *glandulæ agminatæ*. These are more numerous in the lower part of the small intestines, and are situated on that part of the tube most distant from the attachment of the mesentery. Solitary glands are also found in the large intestines. Their use is not very well known. By some they are supposed to pour out their secretion upon the mucous membrane by temporary communications; by others they are supposed to be connected with the lacteal system, in the process of absorption, since they are found larger and more developed during the digestive process than during fasting. Besides, in typhoid fever, these glands are liable to become inflamed and ulcerated. This is probably due to the irritation produced by the absorption of noxious matters from the intestines. Those who hold that these glands are organs of excretion, maintain that the ulceration is due to the irritation produced by the elimination of poisonous matter from the blood. In phthisis they may become the seat of tubercular deposit, which softens and ulcerates, resulting in a troublesome form of diarrhœa.

INTEGUMENT.

The integument resembles the other membranous expansions in its general structure, and might be considered as an everted mucous membrane. It covers and protects the body, allows of motion, and merges gradually into the mucous membrane at the outlets of the body.

It consists of three parts, the *epithelium, basement membrane,* and the vessels, nerves, lymphatics, etc., imbedded in areolar tissue, called the *corium* or true skin (cutis vera.)

Fig. 51.

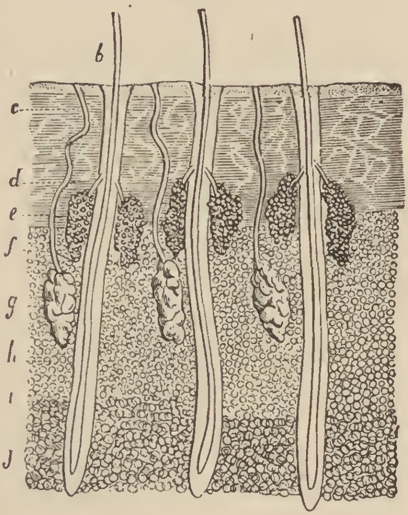


Diagram of the skin, from the scalp; *a*, epidermis; *b*, stem of a hair; *c, f, g*, sudoriparous gland; *d, e*, sebaceous gland opening into the hair follicle; *h, i*, adipose tissue; *j*, bulb of the hair.

EPITHELIUM, (here called *epidermis*). This is not permeated by vessels, is much thicker than in any other membrane, and consists of several layers of cells united by cement substance. The first layer, or those which are next the basement membrane are columnar or rounded, and nucleated, called the mucous layer (rete mucosum or Malpighian layer.) Surrounding these, on the basement membrane, are seen nuclei and granules. The next series of cells are oval, sometimes polygonal from pressure; the next elongated, and the superficial layer flattened, hard and scaly, being hardened by desiccation and secondary deposit. The cells of the deep layer are about $\frac{1}{3000}$ of an inch (8 mmm.) in diameter; the superficial, $\frac{1}{600}$ (42 mmm.) The epidermis covers the whole surface, and is not very uniform in thickness, being very thin in the groin and axilla, and thick in the palms of the hands and soles of the feet. The thickness of the cuticle, in some parts of the feet, gives rise to corns. The development of the cells takes place at the basement membrane, and as they approach the surface they become changed in shape, and ultimately fall off by a gradual process of desquamation. In some of the exanthemata, as scarlet fever, measles, etc., a complete desquamation

of the cuticle takes place during recovery. In the serpent tribe an exuviation occurs annually. The outer layers of cells, when exposed to the action of acetic acid, swell out and become rounded, showing their original shape. A solution of caustic potash also makes them rounded, and completely destroys the deep or mucous layer, as it is called. The epidermis is pierced by the hair follicles, sudoriferous ducts and sebaceous follicles; these openings are called *pores.* In chemical composition it resembles hair, horn, nails, etc. In parts subjected to irritation, as the integument of the laborer's hand, and beneath corns, the vascular supply of the cutis is increased, in order to supply the cells more abundantly.

COLOR.—The color of the different races is due to the development of minute particles of pigment matter, from $\frac{1}{10000}$ to $\frac{1}{20000}$ of an inch in diameter (2.5 to 1.25 mmm.), in the interior of some of the cells of the mucous layer. These cells are therefore called *pigment cells,* and are very numerous in the Ethiopian race. The coloring matter gradually diminishes towards the surface of the epidermis. The development of pigment is increased by the influence of light, as is seen in the change of color in persons removing to warm climates, and in the new-born infants of the negro, which are not very dark-skinned till after the lapse of a few days.

Fig. 52.

Pigment cells.

Pigment cells are also found in the choroid coat of the eye, iris, hair, the areola of the nipple, and other parts of the body in pregnant women, nævi, freckles, etc. They may assume different shapes; some are rounded, as those of the epidermis; others polygonal, as the epithelium lining the inner surface of the choroid coat of the eye; while those imbedded in the substance of the choroid present a remarkably stellate appearance (Fig. 52). Those which line the inner surface of the choroid contain a large quantity of pig-

ment granules. Pigment granules, when viewed separately, are transparent; but when viewed collectively have a dark color, and are seen to move about when set free from the cell, sometimes even when contained in it. In their chemical nature they resemble the cuttle-fish ink, which derives its color from the pigment cells lining the ink-bag. Pigment contains from forty to sixty per cent. of carbon. In some persons there is an entire absence of pigment, as in the *albino;* the hair and skin are unusually white, and the iris has a pinkish hue.

BASEMENT MEMBRANE.—The basement membrane covers the cutis or corium, supports the cells of the epidermis, and regulates osmosis. It is distinctly seen in the integument of the fœtus, but is not perceptible in the adult.

CORIUM, OR CUTIS VERA.—The corium consists of vessels, nerves, lymphatics, a few nonstriated muscular fibre-cells, and some fat, imbedded in areolar tissue (Fig. 51). The meshes of the areolar tissue are very small towards the surface, but are larger towards the subjacent tissue. In parts where strength is required, the white fibrous tissue predominates; where there is much motion, the yellow elastic. The yellow fibres usually take a horizontal course, and give off branches which enclose lozenge-shaped meshes, among which the white fibres twine in great profusion. The contraction of the integument is due to the presence of nonstriated muscular fibre-cells, termed the *arrectores pilorum.* They are found throughout the whole extent of the cutis, some of them surround the papillæ and hair-bulbs, and give rise to that peculiar roughness of the surface called *cutis anserina,* as is seen in the cold stage of intermittent fever. They are very abundant in the cutis of the scrotum (the dartos). Fat is found in the meshes of the deeper parts of the corium, forming a soft bed on which the skin rests, giving rotundity and symmetry to the body, and from being a bad conductor, it prevents the too rapid escape of caloric. The integument may be tanned by any substance which will precipitate the

collagen, as oak bark, hemlock bark, etc., the tannic acid of which unites with the collagen.

APPENDAGES OF THE INTEGUMENT.

These are the *papillæ, nails, hair, sebaceous* and *sudoriferous glands* and ducts.

PAPILLÆ.—The external surface of the corium is raised into papillary eminences, carrying with them the basement membrane. They are irregular in size and frequency, except in the palms of the hands, soles of the feet, and surrounding the nipple. The average size of the papillæ is $\frac{1}{100}$ of an inch in length, and $\frac{1}{250}$ of an inch in diameter at the base. The interior of the papillæ consists of capillaries, nerves, and lymphatics, in areolar tissue. The nerves, as in all finer divisions, are destitute of the white substance of Schwann, and therefore difficult of demonstration. They appear to terminate in many of the more sensitive papillæ, as those of the hand and lips, in oval-shaped bodies called tactile corpuscles (Fig. 46, A). These bodies are generally regarded as little masses of connective tissue surrounded by elastic fibres. In some papillæ, as those of the lips, tongue, palate, and the integument of the glans penis, the nerves terminate in small round or oval-shaped bodies, $\frac{1}{600}$ of an inch in diameter (42 mmm.), named by Krause "end bulbs" (Fig. 46, B). In the general surface of the body the papillæ are few in number, especially on the back; but in the palms of the hands, and soles of the feet, they are numerous, and attain a large size, and are so arranged as to form ridges on the surface, which are generally more or less curved and separated by grooves. This appearance can be seen with the naked eye. Each ridge is produced by a single or double row of papillæ projecting from the surface of the cutis, and covered with the epidermis. The papillæ in each row are generally arranged in pairs side by side, each pair being separated from the next adjacent pair by transverse grooves which cross the ridges at right angles. In the centre of each

transverse groove may be seen the orifice of a sweat duct. In a square inch of the palm may be seen twenty ridges, or forty rows of papillæ, and rather more than sixty pair in each row.

The office of the papillæ is sensation or touch, and to increase the surface for cell development. They are covered and protected by the epidermis, which also fills in the spaces between them.

NAILS.—The nail is an extension of the epidermis, very much hardened, in order to form a protective covering for the dorsal surface of the terminal phalanges of the hands and feet. Each nail consists of a root, body, and extremity. The cutis is folded upon itself so as to form a groove, in which the root and body of the nail are imbedded; this is called the matrix, because it is the seat of growth. Near the root of the nail may be seen a semi-elliptical white spot, called the *lunula*. The structure of the nail is the same as the epidermis; it consists of several layers of cells in cement substance, the deep one being rounded, the next oval or elongated, and the upper series flattened and very much hardened. The latter, when acted upon by acetic acid or caustic potassa, become rounded like the mucous layer, and imperfect traces of the nuclei may be detected. This proves that they are mucous cells, changed in shape, and hardened by the deposit of horny matter. The nail is traversed longitudinally by ridges and grooves, which are apparent to the naked eye, for the purpose of increasing the cell-forming surface. The vascular and nervous supply is very abundant in the matrix. In long illness, particularly of the mucous surfaces, the nails are marked by a transverse groove, the size of which is an index of the length and severity of the disease. It is caused by the abridgment of the nutritive process for the time being. This peculiarity is taken advantage of by fortune-tellers, gipsies, etc., who, by examining the nail, are able to tell the person when he was sick, and the duration of the illness, from the size of the groove

and its distance from the root. The nail increases in length by the development of cells at the root, and on the under surface of the body, which push it onwards in its growth. The finger nails grow at the rate of about $\frac{1}{5}$ of a line per week, and the toe nails about $\frac{2}{5}$ of a line per month.

Fig. 53.

Hair in its follicle, magnified 50. a, stem cut short; b, root; c, bulb; d, hair cuticle; e, internal, and f, external root-sheath; g, h, dermic coat of follicle; i, papilla; k, k, ducts of sebaceous glands; l, corium; m, mucous layer of epidermis; n, upper flattened layers of epidermis; o, upper limit of internal root-sheath. (Kölliker).

Hair.—Hairs are found on all parts of the surface of the body, except the palms of the hands and soles of the feet, and vary in length, shape, and thickness. They are implanted in a saccular cavity called the hair follicle, which is formed by an involution or dipping of the basement membrane into the corium, carrying with it the epidermic cells, the superficial layers of which become rounded. This follicle is larger at the bottom than at the top, to correspond with the bulbous enlargement of the hair, and presents in the bottom a highly vascular papilla covered with cells, from which the hair grows. A hair consists of a *root*—or that part imbedded in the follicle; a *shaft*—the part which projects from the surface; and the *extremity*, which is sometimes split. The root is the thickest part, and presents a bulbous enlargement. The diameter of the shaft varies from $\frac{1}{250}$ to $\frac{1}{1500}$ of an inch (100 to 16.6 mmm.), and is divided into two parts—the *cortical* and *medullary* portion; the former predominates in the human subject. In structure it resembles the epidermis. On section it is seen to consist of cells and cement substance. In the medullary portion they are rounded; but toward the circumference of the cortical portion, they first become oval,

then elongated or fusiform, and finally flattened and hardened, and the latter are so arranged as to present an imbricated appearance (Fig. 54). If the finger be passed along the hair from the extremity to the root, a distinct roughness is felt, owing to this peculiar arrangement of the cells. The external surface presents fine, sinuous cross lines, and a jagged boundary, caused by these imbrications. If a longitudinal section be made, the cortical substance presents a fibrous appearance, caused by the arrangement of the elongated cells in a linear manner. A few pigment cells may be seen scattered irregularly among the fibres of the cortex, but they are more abundant in the medulla. The color of the hair depends on their presence. The coloring matter consists of melanine, and is readily bleached by chlorine. It is stated that the hair has grown white in a single night from the influence of some depressing passion, as fear, etc. It must, however, be a very rare occurrence, and can only be explained upon the supposition that some peculiar fluid is secreted at the papillæ, which percolates through the hair and destroys the coloring.

Fig. 54.

A section of hair magnified and showing the imbricated appearance.

The hair is increased in length by the development of cells on the papilla at the bottom of the follicle, which push it upwards. The cells which are developed in the papilla are originally rounded, and those which grow on the summit continue so throughout the medulla to the extremity of the hair; while those which grow from the sides soon become flattened and imbricated as they pass upwards on the exterior of the hair. In some animals the papillæ are large, and prolonged upwards in the central part of the hair above the surface of the body, and hence they bleed when cut or extracted. In the disease of the hair called *plica Polonica*, the papillæ are said to be elongated, and bleed when cut close to the skin. The hair in these cases grows very fast, and becomes matted together by a glutinous secretion. Some

of the sebaceous glands open into the hair follicle, and pour out an oily secretion which keeps the hair smooth and glossy.

Development of the Hair Follicle.—At about the sixth week of fœtal life, there is first seen a slight depression or inversion of the basement membrane lined by the epidermis, forming the rudimentary follicle. It then becomes deeper, narrower, and flask-shaped, containing cells; those in the centre, fusiform in shape, are arranged in a line, and form the rudimentary hair. At this time also, the papilla springs from the bottom of the follicle. The first brood of hairs are temporary, like the deciduous teeth. After birth the follicles deepen, and a new papilla is formed at the bottom of each, from which the permanent hair is developed, the old hairs being cast off. When a hair is plucked out, the follicle fills with blood, which after a little disappears, and if the papilla is not destroyed, a new hair will spring up. Anything that interferes with the vascular supply at the base of the hair, will affect its growth and cause it to fall out. The growth of the hair may be promoted by the application of certain stimuli, as tincture of cantharides, bay-rum, etc.; these form the bases of hair restoratives.

Sebaceous Glands.—These glands are found in most parts of the integument, except the palms of the hands and soles of the feet. They are very abundant on the scalp, face, axilla, groin, etc., and open either upon the general surface, as on the face; or into the hair follicles, as on the scalp (Fig. 51). Each gland consists of an involution of the basement membrane, lined by the rounded or mucous layer of epithelium. Sebaceous matter is secreted from the capillaries beneath the basement membrane by these cells, which at maturity break down, and throw out their secretion either on the surface of the body, or into the hair follicles. In some cases the gland is lobulated or sacculated in order to increase the secreting surface. In the scalp

there are two of these glands to each follicle, into which they pour their secretion, for the purpose of lubricating the hair. The excretory ducts are generally short and straight, and in some parts of the body, as the face, they become the habitat of a parasitic animal the *Steatozöon Folliculorum.* These are more common about the time of puberty, and in those possessing a torpid skin. The sebaceous matter which covers the fœtus is called the *vernix caseosa.*

The development of the sebaceous gland is similar to that of the hair-follicle. At about the sixth month there is seen a knob-like depression of the basement membrane of either the general surface or the hair follicle, as the case may be. This soon becomes deeper and narrower at the mouth, until it assumes a flask-shaped appearance, and is lined by the rounded layer of epithelium.

Ceruminous and Odoriferous Glands are varieties of the *sebaceous.* The ceruminous secrete a waxy material which entangles particles of dust, insects, etc., and prevents their access to the delicate membrane of the tympanum.

Sudoriferous Glands.—These are situated in the deep part of the corium and subcutaneous areolar tissue, being surrounded by adipose, and open by a duct upon the surface of the epidermis, (Fig. 51). Each gland is formed by a simple involution of the basement membrane, carrying with it the deep layer of cells, and terminating in a convoluted tube beneath the corium. Sometimes the tube is branched, the branches being rolled up in one clump, and held together by areolar tissue. The duct, as it passes to the surface, takes a tortuous course through the corium, upon the surface of which it loses the basement membrane and is continued on through the epidermis in a spiral course, the calibre being larger, and the walls of the duct being wholly formed by the layers of cells. It opens on the surface obliquely, by a valve-like aperture, formed by the scaly epithelium. The openings are called pores, and as many as 2,800 on an average, exist on each square inch

of surface. The number of square inches of surface in an ordinary sized man is about 2,500, therefore the number of pores will be about 7,000,000. Each duct is about one-fourth of an inch in length when unravelled, and the total length of tubing about twenty-eight miles. This is a very important and extensive excretory surface.

FUNCTION OF THE SKIN.—It serves as a protective covering for the body, and possesses, toughness, flexibility and elasticity—due chiefly to the presence of areolar tissue in the corium. It possesses both the function of absorption and secretion. Absorption is carried on through the lymphatics and capillaries of the corium. This may be proved by immersing the body in a bath, when its weight is found to be increased; and not only water, but also substances dissolved in it, may be thus introduced. In severe cases of dysphagia, life may be prolonged by the use of nutritious enemata, and baths of milk and water, beef tea, etc. It is in this way that the *modus operandi* of liniments may be explained. Certain preparations of mercury rubbed in the skin, are readily absorbed in sufficient quantity to affect the system. A secretion of watery fluid or perspiration is continually going on from the extensive system of glands. It generally passes off in the form of vapour, forming *insensible* perspiration, but when considerably increased, the fluid remains in the form of *sensible* perspiration on the surface of the skin. The *perspiration* is a colorless watery fluid, of an acid reaction, and has a peculiar odor, which varies in different parts of the body. It consists as follows:

Water	995.00
Fatty Matter and Cholesterine	.05
Alkaline Sulphates and Phosphates	.05
Sodium and Potassium Chlorides	2.40
Formic, Acetic and Butyric Acid	2.45
Ammonia (urea)	.05
Total	1000.00

The function of perspiration is to regulate the tempera-

ture of the body. The natural temperature is about 98° to to 100° F., and a variation of from 8° to 9° from the natural standard usually proves fatal. When the surface is exposed to a high degree of heat, the glands pour out an increased amount of fluid. This is immediately converted into vapor, and in passing from the liquid to the gaseous state, so much heat becomes latent that the surface is cooled down to the natural standard. When the air is dry, so that evaporation is not interfered with, a very high temperature—from 300° to 400° F.—can be borne with impunity; but if the air be saturated with moisture, evaporation is retarded, and the body suffers; and if the exposure be long continued, death is the result. The amount of perspiration may be diminished by a cold, damp, atmosphere, and increased by heat, exercise, or excitement. The quantity of fluid thrown off by the skin varies very much, according to the state of the atmosphere and the action of the kidneys, the average amount thrown off in the course of twenty-four hours being from $1\frac{1}{2}$ to 2 pounds. In cold weather, when the skin is less active, the kidneys take on increased action, in order to compensate the deficiency. Whatever tends to produce dilatation of the vessels of the skin, increases the quantity of fluid, and contraction diminishes it. Increased nervous action induces copious perspiration, as in great excitement, crises of disease, night sweats, etc., and any substance which will allay nervous action, as atropine, will diminish the amount of perspiration. When the action of the skin is interfered with, as in burns, scalds, covering with large plasters, coating with varnish, or in scarlatina, there is a determination of blood to the kidneys, and some of the albumen escapes. This accounts for albuminuria in the exanthemata.

An interchange of gases or process of aëration also takes place through the integument, carbonic acid being liberated and oxygen absorbed.

A most important function of the skin is the sense of

touch. This varies greatly in different parts, being greatest at the extremities of the fingers, the lips, the tongue, and least in the trunk, arms and thighs. Thus the two points of a pair of compasses rendered blunt may be separately distinguished by the point of the finger when only one-third of a line apart; while they require to be thirty lines apart to be separately felt on the integument of the spine, arm, or thigh. This is owing to the unequal distribution of the papillæ of the corium. Parts that are sensitive to tickling, as the axillæ and soles of the feet, are comparatively blunt in regard to the appreciation of distance. Impressions made on the integument continue perceptible for a considerable time after they have been removed, as *e. g.*, the pressure of the ring, if long worn, is felt on the finger for some time after its removal, and is apt to deceive the individual.

The integument, when wounded, is not restored in all its integrity; the cicatrix presents no hair follicles or glands, and the sensation is abnormal.

CHAPTER V.

DIGESTION.

Digestion is that process by which the food is prepared for absorption and assimilation. The digestive process consists of seven different stages, *prehension, mastication, insalivation, deglutition, chymification, chylification* and *defœcation.* It will be most convenient to treat of these different processes in their order, giving the mechanism and the changes which each is capable of effecting in the food. Before proceeding, it will be profitable to examine the various kinds of food suitable to the nourishment of the human body.

Food.—The *food* of man consists both of organic and inorganic substances. The best classification is that of Dr. Prout, in which the different kinds of food are divided into four groups:

1st. The *Aqueous Group.*—This forms part of the food of all animals, and enters largely into the composition of the body.

2nd. The *Saccharine Group.*—This group is derived chiefly from the vegetable kingdom, and comprehends sugars, starch, gums, vinegar, &c. They consist of carbon, hydrogen and oxygen, the two latter in the proportion to form water.

3rd. The *Oleaginous Group.*—It includes oils, fats and alcohol. They resemble, in elementary composition, the preceding group, except that the carbon and hydrogen exist in nearly equal proportions.

4th. The *Nitrogenous* or *Albuminous Group.* All substances belonging to this group contain nitrogen, as fibrin, albumen, casein, gelatine, gluten, etc. They are chiefly derived from the animal kingdom. Gluten is the nitrogenous

principle of vegetables. They are sometimes called *histogenetic substances.* To these may be added a *Mineral* or *Saline Group,* as sodium chloride, calcium phosphate, etc.

Milk is found to contain ingredients embraced in the preceding groups, and hence it is well adapted to the growth and development of the young. The aqueous group is represented by the water, the saccharine by the sugar of milk (lactose), the oleaginous by the butter, the nitrogenous by the casein, and the saline group by sodium chloride, calcium phosphate, etc., which the milk contains. From the above it will be seen that the food of man is naturally subdivided into two great classes; the *non-nitrogenous* embraced in the 1st, 2nd and 3rd groups, and the *nitrogenous,* which embraces the 4th group; the former supplying a large amount of carbon.

Liebig styles the nitrogenous substances, the *plastic elements of nutrition,* and the non-nitrogenous, the *elements of respiration.* The latter term is objectionable, however, inasmuch as those substances are not actually required in the process of respiration. The terms *nutritive* for the nitrogenous, and *calorifacient* for the non-nitrogenous, as proposed by Dr. Thomson, are preferable, or the terms *histogenetic* and *calorific.* In colder climates, a large quantity of the calorifacient elements are necessary to maintain the proper temperature of the body, and the natives instinctively feed on fats and oils; while the natives of warmer climates feed on fruit, which contains less carbon.

From the construction of the teeth, and digestive apparatus of man, a mixed diet would seem to be the most suitable. Both animal and vegetable food is necessary to his highest *mental* and *physical* development. Certain diseases may arise from the want of a proper admixture of fresh vegetable diet, as scurvy. This is due to the absence of the vegetable acids in the system, as citric and malic acid, and may be remedied by their administration alone.

If, on the other hand, the nitrogenous elements be defi-

cient or absent, imperfect nutrition shows itself in the form of ulcers in certain parts of the body, as in the cornea and alimentary canal and the animals die of emaciation. Magendie tried the experiment by feeding dogs for some time on sugar and water alone, and ulceration of the cornea ensued. The same results were observed when the animals were fed on gum alone; and when feed on olive oil and water, or butter, the animals emaciated rapidly, but ulceration of the cornea did not occur.

QUANTITY OF FOOD.—The absolute quantity of food required for the sustenance of the body in health varies with the age, sex, constitution, habit, and the circumstances in which the individual may be placed. It is of considerable importance to know the average amount of food required by each individual. In the diet scale of the British navy, each seaman gets from 31 to 35½ ounces of dry nutritious food daily, 26 ounces of which is vegetable, and the rest animal, together with sugar and cocoa. This is found to be amply sufficient for the support of strength. The soldier is allowed one pound of bread, and one pound of meat per day, with vegetables in their season, and tea, coffee, or cocoa. In the English hospitals, full diet, upon which convalescents are put, consists of half a pound of meat, twelve to fourteen ounces of bread, half a pound of potatoes, one pint of milk, and one pint of beer, or half a pint of porter.

In prisons, if the prisoners are idle, they receive about 25 ounces of solid food per day, 5 or 6 ounces being meat. Some persons consume large quantities of food. The wandering Cossacks of Siberia devour from 8 to 20 pounds of meat daily. It has been ascertained that from 25 to 35 ounces of solid food per day, one-fourth of which should be animal, is sufficient to maintain health. Prof. Dalton estimates the quantity of solid food necessary for a healthy man at 38½ ozs. avoirdupois per day, consisting of bread 19 ozs., meat 16 ozs., and butter or fat 3½ ozs.; and the quantity of water at 52 fluid ounces.

It is also important to determine the proper diet suitable to particular maladies. Thus, in disease of the kidneys, liver or bowels, or in rheumatism, gout, dyspepsia, or fatty deposit, much good may be effected by a well regulated dietetic treatment. For example, in diabetes, a diet of animal food, and the avoidance of starch and sugar, are generally attended by good results. In disease of the liver, a well-regulated nitrogenized diet is more suitable than one abounding in carbon, which would increase the work of elimination in this organ. In diarrhœa and dysentery, bland unstimulating articles of food should be used, and substances containing very little excrementitious matter, and easily digested, as milk, eggs, beef tea, mutton broth, etc. Starch and sugar are bad for the gouty, rheumatic and dyspeptic, for they are transformed into fat, lactic acid, and other substances in the system. When there is a tendency to obesity, a well regulated nitrogenized diet is the best adapted to obviate it.

Quality.—The food should be in a wholesome or undecomposed state. Those who are in the habit of eating decomposed food, or what is commonly called *haut goût*—(highly seasoned)—are liable to zymotic diseases and disorders of the digestive organs, as diarrhœa, etc. These diseases are very prevalent among the inhabitants of the Faroe and Bird Islands, who are in the habit of eating what they call "*rast*," half-decomposed, maggoty flesh and fish. Prize fighters, in training, adopt a very strict regimen, consisting of the lean of beef and mutton, and stale bread, together with about three and a half pints of fluid per day, fermented liquors being strictly prohibited. Two full meals are allowed with a light supper daily, and plenty of vigorous exercise.

Drink.—Water constitutes the natural drink of man, and no other liquid can properly supply its place. The average quantity of water introduced into the system of an adult in 24 hours is about 50 ozs.; therefore its purity is a matter of great importance. Water conveyed in leaden pipes is dan-

gerous, in consequence of the formation of lead carbonate, which is held in solution by the free carbonic acid which the water contains. Salines in excess, produce derangement of the digestive organs; and, as in the case of decomposed food, a small amount of putrescent matter in the water, insidiously introduced into the system, renders it liable to attacks of diarrhœa, and to the inception of zymotic diseases.

The use of *alcohol* in combination with water, or with other substances in the form of fermented liquors, cannot serve as a substitute for water. It precipitates most of the organic compounds whose solution in water is necessary to their assimilation. It cannot supply anything which is essential to nutrition, as it is incapable of forming albuminous compounds. It is merely useful as a calorific agent; but even for that purpose it is inferior to fats and oils. It is also a stimulant, increasing for the time the vital activity of the nervo-muscular parts of the body, and is followed by a corresponding depression of power. As a stimulant it is useful in low forms of disease, to increase the digestive process, to raise the flagging powers, and carry the patient safely through a perilous disease. Beer and porter may also be found useful in various forms of indigestion; the bitter principle which they contain is also slightly tonic in its action. The habitual use of alcoholic liquors is highly injurious. They are poisonous in large doses, and when used in excess, produce a morbid condition of the nervo-muscular parts of the body, as is seen in delirium tremens, and in fatty degeneration of the muscular tissues of the body. Intemperate persons are also more prone to epidemic diseases, as cholera, dysentery, fevers, etc., in consequence of the accumulation of effete materials in the blood, which render it more liable to "*fermentation.*" The power of the body to endure fatigue, or to resist the extremes of heat and cold, is also diminished by the use of intoxicating liquors.

Tea, when used in moderation, limits the loss of weight when the diet is insufficient; prevents the loss of substance

in the shape of urea; diminishes the amount of perspiration; and has no appreciable effect on respiration or circulation; but when used in excess, is stimulating and highly injurious to the nervous system.

COFFEE is more stimulating than tea. When used in moderate quantities, it prevents waste of the tissues, arouses nervous energy, and invigorates the circulation; but in excess is decidedly injurious.

TOBACCO, though not an article of diet, should be referred to in this connection, as in excess it interferes very much with the proper assimilation of the food. Smoking, chewing, and snuffing, are the most barbarous customs of our race. To those unaccustomed to the use of tobacco, it causes nausea, vomiting and purging. In habitual smokers and chewers, it creates thirst and increases the secretion of the saliva and buccal mucus, which, from being mixed with the juice, must be expelled from the mouth. To some people the fumes of tobacco are very disagreeable, and irritating to the lining membrane of the lungs. The application of it to abraded surfaces is very dangerous, and has been known to prove fatal. A substance called *nicotine* is obtained from tobacco, which is very poisonous, almost equalling in activity hydrocyanic acid.

HUNGER.—Hunger is the general want of nourishment in the system ascribed to the stomach. The introduction of food into the stomach alone will not allay the sensation; it must be partially absorbed, and enter the circulation. Hunger is not occasioned by mere emptiness of the stomach; neither can it be due to the secretion of gastric juice, as some have supposed, because that fluid is not secreted, except during digestion, or when some substance is introduced into the stomach. It is more probable that the sensation in the stomach is due to a congested condition of the capillaries, beneath the mucous membrane, excited by the influence of the sympathetic nerves, and communicated or telegraphed to the nervous centre. If the brain is actively

engaged, the telegraphic message is not noticed, and thus the sensation may be dispelled for a time. Division of the pneumogastric nerve annihilates the sensation of satiety, but not of hunger.

Thirst.—Thirst is the general want of fluids in the system referred to the fauces. This sensation may be as effectually allayed by the introduction of liquids into the stomach as by swallowing in the ordinary way, as is seen in cases of cut throat, where the œsophagus is divided. It may also be relieved by injecting fluids into the veins, or by immersing the body in a bath.

Starvation or Inanition.—This is the result of an entire deficiency, or an inadequate supply of food. In starvation the body is greatly emaciated, and usually deprived of its adipose tissue. There is loss of weight, diminution of temperature, general weakness and bloodlessness. The most prominent symptoms of starvation are, first, hunger, which becomes painful, the pain being referred to the epigastric region, followed by a sinking sensation. Next, an insatiable thirst, which is most distressing; the countenance becomes pale and haggard, the eyes wild and glistening; the body exhales a peculiar fetor, the secretions are offensive; the bodily strength fails, and the voice gets weak. The mental powers are at first blunted, and the sleep consists of short naps, disturbed by dreams in which the individual fancies that he is in sight of plenty of food. Towards the close of the process, delirium generally sets in, and death closes the scene, either from sheer exhaustion or from the occurrence of convulsions.

Now, it will be observed that the above symptoms are common to all low forms of disease; and the medical practitioner should be careful in such cases to supply nourishment and stimulants liberally; even the presence of delirium should not deter him from administering beef-tea and brandy.

Life may be supported under entire abstinence from food or drink for a period of eight or ten days; but this period may be prolonged by the occasional use of water.

PREHENSION.

The organs of prehension are the hands, lips, teeth, and tongue. The tongue is used in suction, somewhat like a piston, so as to produce a vacuum, and allow the fluids tc enter by atmospheric pressure. Suction cannot properly take place when the tongue is tied down at the tip, as in tongue-tied children, it being necessary that the tip and sides of the tongue should be brought in contact with the roof of the mouth. In drinking a fluid by means of a suction tube, as a quill or straw, it is found that suction will not take place if the tube is passed too far back in the mouth, behind the floor of the nares, because air enters through the nose, and no vacuum can be produced. The tongue of some animals, as the ant-eater, is covered with a slimy secretion, which entraps the insects. Dogs and cats lap the water by means of the tongue.

MASTICATION.

This is the first process which the food undergoes, and is entirely a mechanical one. It consists in the cutting and trituration of the food by the teeth. The principal organs are the teeth, tongue, and muscles of mastication.

Teeth.—The teeth in all animals are suited to the kind of food which each is destined to use. In the graminivora, some of the teeth are formed for cutting or cropping the food, but the majority of them are broad and flat, for the purpose of grinding it. In the carnivora, the principal teeth are strong, sharp, and pointed, for tearing the food, while the remainder are broad and flat. The teeth of man partake of the nature of both the graminivora and carnivora, as he is destined to feed on both animal and vegetable food. In some animals, as fish and reptiles, which swallow their food entire, the teeth are only organs of prehension, and are curved backwards to prevent the escape of their prey. Some of the lower animals, as the crustacea, are provided with teeth in the stomach. (For structure of teeth see page 79).

TONGUE.—The tongue is an important organ of mastication, and being the seat of taste, it receives accurate impressions of the kind and quality of the food. While the food is being triturated, the tongue is engaged in moving it from side to side, in collecting the scattered fragments from different parts of the mouth, and bringing them within the range of the teeth. This action is accomplished by the muscles which belong to this organ. The cheeks also assist more or less in moving the particles of food, and keeping them within the range of the teeth.

The *muscles of mastication* are the temporal, masseter, external and internal pterygoid, and digastric. They all act upon the lower jaw, which is capable of being moved in different directions, for the purpose of triturating the food. The temporal, masseter and internal pterygoid elevate the lower jaw, and close the mouth. The posterior fibres of the temporal and the deep part of the masseter carry it upwards and backwards. The external and internal pterygoid, and superficial part of the masseter, draw it upwards and forwards. Both pterygoids draw it from side to side, and it is depressed by the action of the digastric muscle.

The contour and structure of the temporo-maxillary articulation are well adapted to the performance of these various movements. The presence of a plate of inter-articular fibro-cartilage serves, by its elasticity, to distribute the pressure caused by the action of these muscles. It also gives ease to the gliding movements, and serves as a socket for the condyle of the lower jaw, when the latter is drawn forwards by the external pterygoid muscle. Some of the fibres of this muscle are attached to the anterior margin of the plate of cartilage.

Mastication is partly voluntary, and also partly reflex or involuntary. The principal nerves concerned are the *sensory* branches of the fifth and the glosso-pharyngeal, and the *motor* branches of the fifth and ninth cerebral nerves.

INSALIVATION.

The food in its passage from above downwards is acted upon by five different fluids, viz., *saliva, gastric juice, intestinal juice, pancreatic juice,* and *bile,* each of which is of a more or less complex nature. During the process of mastication, the food is mixed with the saliva. This substance is a mixture of four distinct fluids which differ from each other in their chemical and physical properties, viz.: the secretion of the parotid gland, the submaxillary, the sublingual, and the buccal glands. The parotid gland is situated beneath the ear, close to the temporo-maxillary articulation, and opens into the mouth by its excretory duct (Steno's), opposite the second molar tooth of the upper jaw. The submaxillary gland is situated beneath the lower jaw, and communicates with the mouth through Wharton's duct, which opens on the side of the frænum linguæ. The sublingual gland is situated beneath the tongue, near the symphysis of the lower jaw, and opens into the mouth upon an elevated crest of mucous membrane (which may be felt by the tip of the tongue), by fifteen or twenty openings (ductus Riviniani).

Structure of the Salivary Glands. — The salivary glands consist of numerous lobes made up of smaller lobules connected together by areolar tissue, vessels, nerves, etc. Each lobule consists of numerous vesicular pouches, or *acini* which open into a common duct; these vesicular pouches are about $\frac{1}{500}$ of an inch in diameter (50 mmm.) lined by a layer of rounded or glandular epithelium, and surrounded by capillaries and nerves. The cells which line the pouches and ducts are smaller than those which secrete the saliva. The secretion of saliva is stimulated by the presence of food or other substances in the mouth; even the sight or idea of food, or its presence in the stomach, causes the mouth to "water." At other times the secretion is very limited in quantity. The amount secreted in twenty-four hours is

variously estimated at from one to three pounds avoirdupois.

SALIVA.—Saliva is a slightly viscid, transparent fluid, depositing, on standing, a little flocculent sediment, consisting principally of scaly epithelium of the mouth, small nucleated cells from the glands or ducts, granular matter, and oil globules. Its specific gravity is about 1005; usually alkaline, but often neutral, and sometimes slightly acid in its reaction. It is alkaline during digestion ; and neutral during fasting owing to admixture with the acid mucous of the mouth.

COMPOSITION OF SALIVA.—(Bidder & Schmidt) :

Water	995.16
Organic matter, (ptyalin or salivin)	1.34
Potassium Sulphocyanide	.06
Calcium, sodium and magnesium phosphates.	.98
Sodium and potassium chlorides	.84
Epithelium and gland cells	1.62
	1000.00

It is also said to contain a trace of albumen, and some oil globules ; it therefore becomes slightly turbid on boiling, or by the addition of nitric acid. The *ptyalin* gives the saliva its viscidity ; it is coagulated by alcohol, but not by heat. Potassium sulphocyanide may be detected by iron chloride, which produces the characteristic red color of iron sulphocyanide.

The saliva from the parotid gland is a clear, limpid, watery fluid, having a distinctly alkaline reaction. It may be readily obtained by introducing a silver canula, $\frac{1}{20}$ of an inch in diameter, into the orifice of Steno's duct. The quantity of organic matter in the parotid saliva is large, when compared with the mineral ingredients. The submaxillary saliva differs from the parotid secretion in being somewhat viscid, and more strongly alkaline. It may be secured by inserting a canula into Wharton's duct. The saliva from the sublingual gland is also alkaline, and more viscid than the preceding.

The secretion from the buccal glands and mucous membrane is obtained by ligating the ducts of the parotid, submaxillary, and sublingual glands, to exclude their secretion, and then collecting the fluid subsequently secreted in the mouth. This fluid is small in quantity, and much more viscid than either of the preceding secretions.

FUNCTION OF SALIVA.—It possesses the property of converting boiled starch into dextrin and sugar, if kept in contact with it a short time, at the temperature of 38° (100°F.) This *amylolytic* action is due to the presence of the organic matter or *ptyalin* which acts as a ferment.* This, therefore, was formerly supposed to be the true physiological use of saliva, viz. : to dissolve or digest the starchy portions of the food. It was very soon noticed, however, that in the ordinary process of digestion the starchy matters do not remain long enough in the mouth for this change to take place, but pass at once into the stomach, where the further conversion of starch into sugar is retarded by the presence of the gastric juice. The most important use of the saliva is to moisten the food and facilitate its mastication, to lubricate the mass or bolus, and to assist in its passage during the process of deglutition. The watery fluid of the parotid gland is useful in the process of mastication ; while the more viscid secretion of the other glands, and buccal mucus, serve to lubricate the triturated mass, and facilitate its passage down the œsophagus. The tonsils also secrete a viscid fluid, which serves to lubricate the bolus of food during swallowing. During mastication, the saliva is intimately mingled with the mass, and may in this way mechanically enable the gastric juice to penetrate more readily every part, as it enters the stomach. It was observed by Spallanzani that food enclosed in perforated tubes, and introduced

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*There are two classes of ferments, *organized* and *unorganized*. The action of the former is dependent on the life of the ferment, as for example the yeast plant whose fermentative activity depends on the life of the yeast cell ; the latter is not a living organism.

into the stomachs of living animals, was more readily digested when previously mixed with saliva, than when mixed with water. The salivary glands are not very active in infants until the age of six months, and they are therefore incapable of properly digesting starchy food, corn flour, etc.

DEGLUTITION.

The organs of deglutition are the mouth, tongue, pharynx, and œsophagus. The mechanism of deglutition may be divided into three stages. In the first the food, when properly masticated, is formed into a bolus on the tongue, and carried backwards through the anterior pillars of the fauces, by that organ, and forced into the pharynx. This is done by the pressure of the tongue against the roof of the mouth —the pressure commencing at the apex, and ending near the base. During the second stage, the hyoid bone is carried upwards and slightly forwards by the anterior belly of the digastric, mylo-hyoid and genio-hyoid, the pharynx is raised by the stylo-pharyngeus and palato-pharyngeus to receive the bolus, the epiglottis is pressed over the aperture of the larynx, by the elevation of the pharynx and larynx towards the base of the tongue, and the bolus glides past. The base of the tongue is now drawn slightly upwards and backwards by the posterior belly of the digastric and stylo-hyoid, the palato-glossi (or constrictors of the fauces) contract, and prevent the return of the bolus into the mouth, the soft palate is raised by the levator palati, the palato-pharyngei contract and come nearly together, the uvula filling up the space between them, and in this way the food is prevented from passing into the posterior nares. In the third stage, the constrictors of the pharynx contract upon the bolus from above downwards, and force it into the œsophagus, which, by virtue of its peristaltic action, urges it onwards to the stomach. The first act is voluntary ; the second and third are involuntary. The nerve centre for

deglutition is the medulla oblongata; the nerves concerned in the act are, the sensory branches of the fifth, glosso-pharyngeal and pneumogastric nerves, and the motor branches of the fifth, facial, hypoglossal, pneumogastric and spinal accessory.

VOMITING.—In the mechanism of vomiting, the process of deglutition is exactly reversed. This may be caused by the administration of direct or indirect emetics, by mental emotion, as the sight of a disgusting object, by any unusual motion, as sailing, swinging, &c., by nervous shock, as in the case of severe wounds, by derangement of the system, or the presence of irritating substances of any kind in the stomach, or obstruction to the passage of the food through the bowels. Its *rationale* may be explained by the theory of reflex action. The irritation or impression being applied to the periphery of the nerves, is first conveyed to the nervous centres (medulla oblongata), and thence a motor impulse proceeds, by which an impression is made upon those parts concerned in the act of vomiting, through the nerves which are distributed to them. The medulla oblongata may be affected directly by the presence of particular substances in the blood, or causes acting directly on the centre itself. The motor nerves implanted in it are thus stimulated to action, and the abdominal muscles, diaphragm, muscles of the larynx and pharynx, as well as the muscular fibres of the stomach or œsophagus, are thrown into contraction.

First, a deep inspiration is taken; the aperture of the glottis is closed, and the lungs being filled with air, the diaphragm is fixed. The glottis is closed by the elevation of the larynx against the base of the tongue. The pharynx is raised, the palato-pharyngei contract and close the posterior nares, the uvula filling the small interval between them, and thus the fluids are prevented passing through the nose. This constitutes the first act. Then the stomach contracts and is compressed against the diaphragm by the

contraction of the abdominal muscles; the pylorus is closed, and the contents are forcibly ejected, their passage being facilitated by the anti-peristaltic action of the stomach, œsophagus and pharynx.

CHYMIFICATION.

This process takes place in the stomach, through the agency of the gastric juice. The walls of the stomach consist of three coats; an external peritoneal or serous membrane; a middle muscular, consisting of longitudinal, circular and oblique fibres; and a mucous coat; with vessels, nerves and lymphatics, all held together by areolar tissue. A delicate form of connective tissue is found in, or immediately beneath the mucous membrane, called *reticular* or retiform tissue, the meshes of which contain lymph corpuscles. There are also some nonstriated muscular fibres called *muscularis mucosæ.* The mucous membrane of the stomach is lined by columnar epithelium, and when examined by a lens, it presents a peculiar honeycombed appearance, caused by a number of shallow depressions or alveoli of a polygonal or hexagonal form, which vary from $\frac{1}{100}$ to $\frac{1}{350}$ of an inch in diameter, separated by slight ridges. In the bottom of each alveolus may be seen the orifices of minute tubes, the gastric follicles. They are arranged perpendicularly, side by side, short, and tubular in character towards the cardiac end; but near the pyloric extremity, they are more thickly set, convoluted, and terminate in dilated saccular extremities, or divide into from two to six branches, the object of which is to increase the extent of surface for secretion (Fig. 48). The follicles consist of an involution of the basement membrane, lined with cells, and are divided into two varieties, which differ only in the character of the cells which line them, and the secretion which they produce, viz: the *mucous follicles* and *peptic follicles.* The former predominate towards the pylorus, and the latter towards the cardiac end. The

mucous follicles are lined with columnar epithelium on the sides, and rounded in the bottom, and secrete the mucus. The deep part of the peptic follicle is filled with large granular spheroidal cells; above this it is lined by rounded epithelium, and the upper part of the follicle is lined with ordinary columnar epithelium. These follicles are supposed to secrete the gastric juice. Besides these, there are the *lenticular glands,* which resemble in structure, function and general appearance, the solitary glands of the intestine. They are situated beneath the surface of the mucous membrane, and are found chiefly along the lesser curvature of the stomach. The mucous membrane of the stomach is abundantly supplied with blood-vessels. These break up into fine capillary plexuses, with oblong meshes, which surround the follicles, and are prolonged upwards to the ridges of mucous membrane bounding the pits or alveoli. The nerves of the stomach are derived from the pneumogastric and sympathetic. In the submucous areolar tissue of the stomach and intestines, there is a fine plexus of non-medullated nerve fibres, known as "Meissner's plexus."

GASTRIC JUICE.—Gastric juice was obtained by Spallanzani from the stomachs of animals, by causing them to swallow sponges, attached to the end of a cord, by which they were afterwards withdrawn and the fluid expressed. It has since been obtained and experimented upon, by Dr. Beaumont, of the U. S. Army, from Alexis St. Martin, a Canadian boatman, who had a permanent gastric fistula, the result of a gun-shot wound. Schmidt has also had opportunities of examining it in a female named Catherine Kütt, who had for three years a gastric fistula under the left mammary gland. It may also be obtained from any of the lower animals, by making an artificial opening through the abdominal walls and inserting a canula.

PHYSICAL APPEARANCE AND PROPERTIES—It is a clear, colorless fluid, of an acid reaction, secreted only during digestion, or as the result of some irritation applied to the

mucous coat of the stomach. Its specific gravity varies from 1001 to 1010. It is not prone to decomposition, and may be kept for an indefinite length of time in an ordinary glass-stoppered bottle. After standing for two or three weeks, a confervoid vegetable growth shows itself in the fluid. This growth has a dendritic appearance, each branch or filament consisting of a single row of elongated cells. The total quantity of gastric juice secreted in twenty-four hours is from ten to twenty pints (Brinton). This would seem almost incredible, did we not remember that the gastric juice is in part reabsorbed, together with the alimentary substances which it holds in solution, after the process of digestion is completed. The secretion of gastric juice is much influenced by nervous conditions. It is diminished by irritation of temper, fear, joy, fatigue, mental exertion, or any febrile disturbance of the system. The gastric juice does not act on the mucous membrane of the stomach during life; but after death this membrane is generally found dissolved and disintegrated by its action. This, according to Pavy, depends upon the alkalinity of the the blood, which circulates freely during life in the walls of the stomach, and which neutralizes the acidity of the gastric juice and destroys its digestive powers on the coats of the stomach.

Chemical Composition of Gastric Juice:

	Human.	Dog's.
Water	994.40	971.17
Pepsine	3.19	17.50
Hydrochloric acid, (free)	0.22	2.73
Sodium, potassium, and calcium, chlorides	2.07	5.87
Magnesium, calcium and iron Phosphates	.12	2.73
Traces of Ammonia		
	100.00	100.00

It was formerly supposed that lactic acid was the acidifying agent of the gastric juice, and in all probability a small quantity is sometimes present; but hydrochloric acid is much the more abundant and important of the two. The

presence of free acid is essential to its physiological properties, for the gastric juice will not exert its solvent action upon the food after it has been neutralized by an alkali.

The organic matter, or *pepsine*, is next in importance. It is precipitated from its solution in the gastric juice by alcohol and various metallic salts; but is not affected by potassium ferrocyanide. It may be coagulated by boiling. Gastric juice which has been boiled, or mixed with a small quantity of bile, loses its property of digesting substances.

FUNCTION.—It dissolves the albuminoid or *nitrogenous* substances (proteids) of the food, and converts them into a substance called albuminose or peptone. The liquefying process which the food undergoes in the stomach is thought by some to be, not a simple solution, but a catalytic transformation produced in the albuminoid substances by the *pepsine*, which acts as a ferment (hydrolytic). The gastric juice will exert its solvent action on the food outside the body, as well as in the stomach, if kept in glass phials upon a sand bath, at a temperature of 100° F. In the digestion of cooked meat, the gastric juice first dissolves the areolar tissue, and thus sets free the muscular fibres, which are subsequently acted upon and dissolved. Some albuminoids, as casein of milk are first coagulated by the action of the gastric juice, and then acted upon similarly to the other solid principles. The albuminoid or proteid substances are acted upon so as to be changed into *albuminose* or *peptone*. This substance differs from ordinary albumen in not being precipitated by heat, nitric or acetic acid, or potassium ferrocyanide, and in being rendered *diffusible*, or easily absorbed. It is readily precipitated by tannic acid or hydrargyrum perchloride. The *peptones* are closely allied to the *crystalloids*, which possess superior osmotic properties as compared with the *colloids*. Some authors describe three sorts, *a*, *b*, and *c*, peptones; other allied substances formed during digestion are named *parapeptone*, *metapeptone*, and *dyspeptone*. After entering the blood vessels, the peptones are

again transformed into albumen, a change which is necessary to prevent their passing out. The saccharine portions of food and dextrine are at once absorbed in the stomach. The amylaceous principles are prepared for the action of the pancreatic juice, by softening the external covering of the starch granules. Fatty tissues are also partly disintegrated and the fatty matter set free, by a solution of the areolar tissue and albuminous cell walls, but the fat itself undergoes no change. The gastric juice also possess *antiseptic* properties, which not only prevents the putrefaction of nitrogenous substances during digestion, but also corrects the effects of partly decomposed substances taken as food.

INFLUENCE OF THE NERVOUS SYSTEM ON DIGESTION.—The function of digestion is arrested by strong mental emotion or serious bodily injuries, and the food is often rejected. The movements of the stomach are due to the presence of food acting as a stimulus to the periphery of the nerves, transmitted to the ganglia, and reflected to the muscular coat. Irritation of the pneumogastric nerves produces increased peristaltic action of the stomach, and division retards or arrests it, and temporarily arrests the secretion of gastric juice. Galvanization of these nerves increases the secretion of the fluid, but diminishes it when applied to the sympathetic.

RATE OF DIGESTION.—The time required for digestion varies in different animals. In the carnivora, fresh raw meat requires from nine to twelve hours. The average time required in the human subject varies from one to five and a half hours, according to the *nature* and *quantity* of food taken.

Dr. Beaumont's table, taken from Alexis St. Martin.

Pigs' Feet	1.00 hour.	Roast Beef	3.00 hours.
Tripe	1.00 "	Roast Mutton	3.15 "
Trout	1.30 "	Veal	4.00 "
Venison	1.35 "	Salt Beef	4.15 "
Milk	2.00 hours	Roast Pork	5.15 "
Roast Turkey	2.30 "		

Artificial Digestion.—An artificial digestive fluid may be made by macerating portions of the mucous membrane of a fresh stomach in water or glycerine, or by dissolving pepsine in water and then adding hydrochloric acid (1 part in 1000.) The fluid thus formed will digest portions of food if kept at a temperature of 98 to 100° F. Such a preparation is very useful in cases where deglutition is impracticable, and in which the body is being nourished by nutritive enemata. It is mixed with the nutritive fluid, which is injected into the bowels. *Pepsine* is administered with benefit in some forms of dyspepsia, but should be combined with hydrochloric acid.

Movements of the Stomach.—These are effected by the alternate contraction of the longitudinal and circular fibres of its muscular coat. The muscular fibres of the orifices also keep the stomach closed during digestion. The movements were observed by Dr. Beaumont, in the stomach of Alexis St. Martin by introducing the stem of a thermometer. This action is more energetic near the pylorus, the bulb being grasped tightly and drawn towards this orifice. The peristaltic action of the coats of the stomach produces a kind of double current of its contents, the circumferential portions being moved towards the pylorus, while the central portions are propelled in the opposite direction, towards the cardiac orifice. The action of the stomach produces a constant movement of the food, and secures its thorough admixture with the gastric juice, which penetrates every particle, and converts it into a greyish pulpy mass of a homogeneous appearance, called *chyme*, which then passes into the duodenum.

CHYLIFICATION.

This process takes place in the small intestine, but principally in the duodenum. For a description of the mucous membrane of the small intestine, see "mucous membranes." It has already been stated that only the

albuminoid substances are digested by the gastric juice. The starch, oils and fats, pass unchanged into the small intestine. Here they come in contact with the mixed intestinal juices, and are reduced to a state fit for absorption. The juices of the small intestine are the *intestinal juice proper*, or the fluid secreted by Brunner's glands and Lieberkühn's follicles, the *pancreatic juice*, and the *bile*. These fluids, in contradistinction to the gastric juice, have an alkaline reaction.

Intestinal Juice.—This may be obtained in a tolerably pure state by ligating the duodenum of some of the lower animals, as the dog or rabbit, just above the opening of the choledoc duct, and establishing a fistulous opening into the duodenum. It is small in quantity, and consists of the secretion from Brunner's glands, mixed with the fluid from the follicles of Lieberkühn, and some mucus.

Physical Appearance and Properties.—It is a colorless, viscid fluid, of an alkaline reaction, closely resembling, in its physical characters, the saliva and pancreatic juice. It possesses the property of converting starch into sugar. The quantity obtained by experimenters has rarely been sufficient for a thorough investigation of its properties.

Function.—It is supposed to aid in the digestion of the amylaceous portions of food. By its action starch is converted into dextrin, and then into sugar (glucose), in which state it is soluble, and thus admits of direct absorption into the blood-vessels, or the sugar may be converted into lactic acid, and in this condition pass into the circulation. The presence of free alkali is as necessary to these changes, as free acid to the solution of the albuminoids by the gastric juice. Boiled starch is more readily digested by all animals than raw ; in fact, boiling is necessary to its ready digestion.

Pancreatic Juice.—This substance is intended to assist in the conversion of starch into sugar, and also to digest the oily portions of the food. It may be obtained from the

dog by inserting a canula in the pancreatic duct (major) through a fistulous opening in the abdomen. The pancreas in structure, resembles the salivary glands and is present in all the vertebrate animals. In the human subject, the pancreatic duct and choledoc duct usually open into the duodenum at the same point. In some of the vertebrata they open at some distance from each other, the pancreatic duct being usually below the biliary.

Physical Appearance and Properties.—It is a clear, colorless, viscid fluid, of an alkaline reaction, somewhat resembling, in its physical character, the salivary fluid. It is coagulated completely by heat, not a drop of fluid being left. It is also coagulated by nitric acid, alcohol, and the metallic salts. The precipitate may be redissolved by the addition of an alkali. The average amount secreted by the human subject in the course of twenty-four hours, is about 12 to 16 ozs. avoirdupois.

Chemical composition of the pancreatic juice of the dog, according to Schmidt; the following is the mean of three analyses:

	Mean.	Extreme.
Water	980.45	900.76
Pancreatine	12.71	90.44
Sodium and Potassium Chlorides	3.43	7.37
Calcium, Magnesium and Sodium Phosphates	.09	.53
Soda, Lime and Magnesia, combined with Pancreatine	.32	.90
Traces of Iron		
	1000.00	1000.00

The most important ingredient is the organic matter, or *pancreatine.* It is coagulated by heat, nitric acid and alcohol. It is also precipitated by magnesium sulphate, and this distinguishes it from albumen.

Function.—It acts upon the oily portions of the food and and fats, partly by splitting them up into fatty acids and glycerine, and partly by disintegrating them, and reducing them to a state of complete emulsion, the mixture being converted into a whitish, opaque, creamy fluid, which is readily absorbed. In disease of the pancreas, which is ex-

ceedingly rare, or occlusion of the duct, the patient invariably suffers extreme emaciation, and in some cases fat appears in the fæces. The pancreas is found in carnivorous as well as herbivorous animals, thus showing that the pancreatic secretion is chiefly intended for the digestion of fatty matters· It also assists in the conversion of starch into sugar, and in this way promotes the digestion and absorption of amylaceous food. It further assists in the complete digestion of albuminous and gelatinous substances which have escaped the action of the gastric juice.

SECRETION OF BILE.—Bile is secreted by the cells of the liver from the blood of the portal vein, and may be readily obtained from its reservoir, the gall-bladder. It is secreted by the hepatic cells, which are situated in the interior of the lobules. When the cells become filled with bile, they break down, and the fluid is then taken up by the minute hepatic ducts which originate in the interior of the lobules. These small ducts, by frequent successive junctions, form two large ducts, each somewhat larger than a crow-quill, which emerge at the transverse fissure of the liver, one from the right and the other from the left lobe. These two ducts, together with the hepatic artery, the portal vein, nerves, and lymphatics, are enclosed in a little areolar tissue called *Glisson's capsule*, and about an inch below their exit they unite to form the hepatic duct, which soon unites with the cystic duct from the gall-bladder, and the union of the two constitutes the ductus communis choledochus. This is about two or three inches long, and passing down behind the first portion of the duodenum, it opens into the second or descending portion, on its inner side, a little below the middle, in connection with the pancreatic duct. The gall-bladder is situated on the under surface of the right lobe of the liver, and serves as a reservoir for the accumulation of the bile. During fasting, the gall-bladder is found full, and it empties itself when digestion is going on. The mechanism is as follows: during the intervals of digestion

the duct below the junction of the cystic is closed by contraction of its muscular fibres, and the bile being secreted finds its way into the gall-bladder, but on the introduction of food into the intestine, the bile is discharged from the gall-bladder by the pressure of the contraction of its coats. Its presence is not essential, for in many animals it is entirely absent, as in some of the fishes, mammals, etc. The hepatic cells contain more or less fat in the form of globules, and this may be regarded as part of their secretion. It is also found to be most abundant when fatty matters are withheld from the food. The fat is formed by the cells, from certain elements of food, as starch, sugar, etc., and is discharged into the duodenum to be reabsorbed by the villi, and carried to the lungs, where it is decomposed by the oxygen in the production of animal heat.

Physical Appearance and Properties of Bile.—Bile is a thick, viscid fluid, of a greenish yellow color, a bitter taste, and a nauseous smell. Its specific gravity is about 1020, and possesses either a neutral or slightly alkaline reaction, When agitated in a test tube it presents a peculiar soap-like foam, the bubbles adhering closely together and remaining for a long time without breaking. The average amount of bile secreted in twenty-four hours is from 30 to 40 ounces. It possesses antiseptic properties, preventing substances with which it is mixed from putrefying. When it is absent in the alimentary canal, as in cases of complete biliary obstruction, the fæces are found to have an intolerable fetor. Bile is constantly secreted by the liver but more actively from one to two and a-half hours after food is taken.

Chemical Composition of Human Bile.—Frerichs:

Water	859.2
Bile Salts (bilin)	91.5
Fat	9.2
Cholesterine	2.6
Mucus and Coloring Matter	29.8
Salts	7.7
	1000.0

A distinguishing feature of bile is the absence of proteids or albuminous substances. The most important ingredients are the coloring matter of the bile, and the bile salts or *bilin.* The coloring matter, *bilirubine,* is a yellowish-red crystallizable substance, of organic origin. It does not pre-exist in the blood, but is supposed to be formed in the liver. In cases of biliary obstruction it may be absorbed, and circulating with the blood, stains the tissues and fluids of the body of a greenish-yellow or saffron color, giving rise to the state called jaundice. It is insoluble in water, very slightly in alcohol; its best solvent being chloroform, or a solution of soda or potassa. It becomes green on exposure to the air, and on the addition of an acid, deposits green flocculi resembling the *chlorophyl* of plants. This is called *biliverdine,* and a small quantity is found in bile. It is more abundant in the bile of the herbivora. Two other coloring matters are found in bile after remaining some time in the gall bladder; also in gall stones, named *biliprasin* and *bilifuscin.*

Cholesterine.—This substance may be removed from bile by agitation with ether, in which it is soluble. It is distinguished from fats, with which it is closely associated, by not being saponified by alkalies. It has also been found in the fluid of hydrocele, ascites, and in the interior of many encysted tumors. It is a crystallizable substance, the crystals having the form of thin transparent rhomboidal plates. Cholesterine is not formed in the liver, but is supposed to originate in the brain and nerve tissue, from which it may be extracted by alcohol or ether, and is discharged by the liver. It is also found in the tissue of the spleen. It is the principal constituent of gall stones.

Bile Salts *(Bilin).*—These consist of sodium glycocholate and taurocholate; the latter predominates in human bile, while the former is more abundant in ox bile. The bilin of the dog, cat and other carnivora, consists exclusively of the latter salt. They are soluble in water and alcohol,

but not in ether. The taurocholate possesses the property, when in solution, of dissolving a certain quantity of fat. These substances may be obtained as follows: the bile is evaporated, and the dry residue treated with alcohol and filtered; this alcoholic solution contains sodium glycocholate and taurocholate, coloring matter, and fats. Ether is now added until a precipitate takes place, which has at first a resinous appearance. After this precipitate has stood from twelve to twenty-four hours, it presents, when examined by the microscope, a number of acicular crystals of sodium glycocholate, and some drops or globules of sodium taurocholate, which resemble oil globules, except in their chemical properties. The glycocholate may be separated from the sodium taurocholate by the following means: The fluid containing alcohol and ether, previously used, is poured off, and the deposit in the bottom of the tube is dissolved in water. To this, lead acetate is added, which gives a precipitate of lead glycocholate, leaving sodium acetate in solution. The precipitate is filtered and decomposed by sodium carbonate, reproducing the original sodium glycocholate. The filtered fluid which remains, containing the sodium taurocholate, is then treated with lead subacetate, which precipitates a lead taurocholate. This is filtered and decomposed by sodium carbonate, as in the former instance. It crystallizes in slender needles, much like the glycocholate. The glycocholates and taurocholates are formed in the liver, being produced by the hepatic cells, and discharged by the ducts. They are not found in the blood. The acids may be separated from their respective salts by boiling with dilute sulphuric or hydrochloric acids, or caustic potash, which also further splits up the glycocholic acid into *glycine* and *cholic* (or cholalic) acid, and taurocholic into *taurine* and cholic acid.

Glycogenic Function of the Liver.—The actual formation of glucose, or grape sugar, in the liver, was first discovered by Claude Bernard in 1848. A substance called

glycogen is first formed, and this is transformed into sugar by the action of a *ferment* formed in the liver. This substance is formed by the liver itself, and is a normal constituent of its tissue. Glycogen is identical in composition with starch, and is found in other tissues besides the liver, viz.: in the muscles, placenta, and embryonic tissues. The liver, when removed from the body of an animal, and the sugar washed completely away, will be found, after a few hours, to contain sugar in abundance. Its presence may be determined in the substance of the liver, and in the hepatic veins, by means of Trommer's test, or by fermentation. It has also been found in the portal vein, owing to the reflux which, in the absence of valves, may take place after death. The sugar thus formed is carried to the right side of the heart, and thence to the lungs, where it is decomposed in the production of animal heat. Puncture of the floor of the 4th ventricle, section of the cervical sympathetic, or inferior ganglion, or irritation of the central extremity of the 8th pair, abnormally increases the glycogenic function of the liver, and sugar is produced so rapidly, that the lungs cannot decompose the whole of it, and therefore it is thrown off by the kidneys, producing what is known as diabetes mellitus. Temporary glycosuria may also be produced by the action of various substances, as the inhalation of ether or chloroform, injection of curare, poisoning by carbonic oxide gas, or by injuries to the brain, and in the course of various diseases. Sugar and fat are both formed in the liver, irrespective of the kind or quality of the food. Pavy and others are of the opinion that no sugar exists in the liver during life, but only occurs after death.

Function of Bile.—During fasting, the bile is stored up in the gall-bladder, but if the fast be prolonged beyond a reasonable time, the bile overflows into the intestine. The flow of bile into the duodenum is caused by the presence of food, or any irritating substance upon the mucous sur-

face of the small intestins. The bile is poured into the duodenum, never below it, a circumstance not very probable if bile were solely an excrementitious substance, since it would have been quite as convenient for nature to have effected its discharge into the hepatic flexure of the colon. When the bile duct is tied, and this fluid prevented from passing into the duodenum, the animal becomes greatly emaciated, and ultimately dies from inanition. There can be no doubt, therefore, that the bile contributes in some way to the complete digestion and assimilation of the food. Bile cannot readily be detected in the fæces, and therefore it is supposed to be entirely changed in its passage through the bowels, or in part reabsorbed with the chyle, and thrown back into the system, to be used in the generation of heat by contact with oxygen in the lungs.

Bile is both an *excrementitious* and *digestive* substance. That it is excrementitious is evidenced in the comparatively large size of the liver and the active formation of bile in the fœtus, and the presence of meconium (biliary matter) as fæces in the intestines. The fæces of the adult also contain the coloring matters, some fatty matter, and a small quantity of bilin. Through the bile is eliminated carbon, hydrogen, and other elements from the blood, which if allowed to accumulate, would render it impure. Dr. Flint regards the excretion of cholesterine, which is changed into stercorine in the bowels, as an important function of the liver. As a digestive it assists in emulsifying the fatty matters, and by reason of its alkalinity favors their absorption. The liver also performs an important office in removing substances which have been taken up by the portal vein during digestion, which would be injurious if allowed to enter the circulation. We may therefore conclude as follows: that the liver secretes a complex fluid, the "*bile*," which is poured into the duodenum. Its coloring matters and some of the fatty matter and salts, are carried off in the fæces forming the natural purgative of the body, and

by virtue of its antiseptic properties, preventing decomposition of the fæcal matters. Its fat and bilin are in great part reabsorbed. It also assists in the complete digestion of those parts of the food which have escaped digestion, as starch and fatty matters. It forms sugar and fat in the circulation, independently of the substances in the food. It eliminates carbonaceous matters; some directly, as the coloring matter, small quantities of fat and bilin; others indirectly, as fat, sugar, and bilin, which pass to the lungs, and are converted into carbonic acid and water by the oxygen.

Tests for Bile.—When nitric or nitroso-nitric acid (Gmelin's test) is added to a mixture containing bile, and shaken, a play of colors is produced, changing from green through various tints to red. This does not indicate the presence of biliary substances proper, but only the coloring matters.

Pettenkofer's Test.—This is the best test for the detection of *bilin.* A watery solution of the bile is mixed with a drop or two of a solution of cane sugar; sulphuric acid is then added to the extent of two-thirds of the liquid, and a red, violet, and purple color are produced in succession. The reaction consists in the liberation of cholic acid from the glyco-cholic or tauro-cholic acid of the biliary salts. The sugar must be used in small quantities, for when added in excess, it is liable to be acted on and discolored by the sulphuric acid. The solution of sugar should be about one part sugar to four parts water. Foreign matters, not of a biliary nature, such as oleine, ethereal oil, amyl-alcohol, albuminous matters, and the salts of morphine and codeine, may produce a similar red or violet color. This may be overcome, however, by first extracting the suspected matters with alcohol, precipitating with ether, and dissolving the precipitate with water, before applying the test.

The *spectrum* of Pettenkofer's test presents characters which may distinguish it from the reactions produced by other organic substances. If some of the colored fluid to

which the cane sugar and sulphuric acid have been added be placed before the slit of the spectroscope, its spectrum shows a broad, dark absorption band at E*, and extending to midway between D and E, the central part of the band being darker than the edges. When an alcoholic solution of Pettenkofer's test is examined as above, two absorption bands are seen; one at E, identical with the one seen in the watery solution; and the other at F, narrower and fainter than the one at E, (Fig. 55).

Fig. 55.

Spectrum of Pettenkofer's test with the biliary salts in alcoholic solution.

Bile is also *dichroic*, or presents two different colors when examined by transmitted light, according to the thickness or thinness of the stratum under examination It is also *fluorescent*, or faintly luminous with a color of its own, especially when examined by the more refrangible rays of the solar spectrum.

SUMMARY.—The digestion of the food is not a simple operation, but consists of several different processes, which occur successively in different portions of the alimentary canal. The food is first subjected to the physical operation of mastication and insalivation in the mouth. It then passes into the stomach, where it meets with the gastric juice, which converts it into a pulpy mass—the chyme. Here certain soluble elements of the food, as water, wine,

* The solar spectrum is crossed by vertical lines known as Frauenhofer's lines, and designated A, B, C, D, E, F, G and H. The situation of an absorption band is indicated by reference to one or more of these letters.

tea, saline matters, sugar, and a certain quantity of albuminose are absorbed by the veins and lymphatic vessels of the stomach. The food then passes into the duodenum, or small intestine, carrying with it the gastric juice, where it meets with the intestinal juices, pancreatic juice and bile. The albuminous matters which were not wholly digested in the stomach are now dissolved; starchy matters are converted into dextrine and sugar, the oils and fats are emulsified, and the fluid is converted into chyle. This is taken up by the lacteals or blood-vessels in the process of absorption, and the coarser portions of the food, or excrementitious matters of the body, are carried off by the large intestine.

Large Intestine.—Its office is mainly confined to the separation and discharge of the fæces. The mucous membrane of the large intestine is destitute of villi, and valvulæ conniventes. Beneath the mucous membrane are found a few nonstriated muscular fibre cells (muscularis mucosæ.) The glands are of two kinds *tubular* or glands of Lieberkûhn, and *lenticular* glands. The former are larger than those in the small intestine, and the latter closely resemble the glandulæ solitariæ, and are most numerous in the cæcum and vermiform appendix.

The ileo-cæcal valve is situated at the junction of the ileum with the cæcum, and prevents reflux of the contents of the latter. It consists of two semilunar folds of mucous membrane, each of which contains vessels, nerves and lymphatics, together with some of the muscular fibres of the intestine. By dividing the longitudinal muscular fibres and peritoneum at the margin of the valves, they may be made to disappear, just in the same way as the sacculi of the large intestine can be obliterated, by a similar operation. The surface of the valve next the ileum is covered with villi, but they are entirely absent on the surface next the cæcum.

It is supposed by some that a certain amout of digestion takes place in the cæcum. In some animals it is very large,

and would seem, without doubt, to exercise some special function in the complete solution of the food. But in man it is quite rudimentary, and has very little action upon the fæces in their passage through. No material change takes place in the fæces as they pass through the intestine, excepting that they become drier the longer they remain in the bowel, owing to the absorption which takes place. Nutritive enemata may also be absorbed by the large intestine. The fæces are urged onwards to the rectum by the vermicular action of the bowel, where they accumulate, and are prevented from escaping by the contraction of the sphincter. The presence of the accumulated fæcal matter in the rectum, causes a sensation demanding its discharge or defæcation.

DEFÆCATION.

This is the expulsion of the fæces from the rectum, and it is effected by the contraction of the muscular fibres of the rectum, assisted by the contraction of the abdominal muscles and diaphragm, which diminish the size of the abdominal cavity, compress the intestines, and thus force onwards the fæcal matter towards the anus. This force is at the same time quite sufficient to overcome the passive contraction or the sphincter. If the rectum be over-distended by fæcal matter, its contractility will be diminished, and immense accumulations may take place. This is apt to occur in aged persons, and the fæcal matter may require to be scooped out. On the other hand, when the fæces do not accumulate in sufficient quantity to distend the rectum, the act of defæcation may be attended with difficulty, and the straining may cause prolapsus ani. Under such circumstances enemata are of great service, by distending the bowel and stimulating it to proper action.

The quantity of fæces depends on the nature of the food and the state of the system. Vegetable food produces a greater amount of fæces than animal, because it contains much that is incapable of reduction in the stomach and duo-

denum. The quantity passed daily in health is from four to eight ounces; so that if we assume thirty-five ounces to be the average quantity of food per day, it may be inferred that about thirty ounces are appropriated for the support of the body.

Analysis of Fæces—

Water	73.3
Excretine, stercorine, salts and fatty acids	.
Insoluble residue of food, coloring matter and other ingredients of bile, mucus and epithelium	26.7

Excretine was discovered by Marcet and is associated with excretolic acid. It is a crystallizable substance, insoluble in water, but soluble in ether and hot alcohol, and is slightly alkaline. The crystals are in the form of four-sided prismatic needles. It fuses at 204°F.

Stercorine was discovered by Prof. Flint, Jr. It has the same crystalline form as excretine, is also soluble in ether and boiling alcohol, but fuses at a lower temperature. It is supposed to be formed from cholesterine.

Salts of Fæces.—These consist chiefly of calcium and magnesium phosphates, iron, soda, lime and silica.

The peculiar odor of the fæces is supposed to be caused by the secretion of the glands. Certain gases are also generated in the bowels. They consist of carbonic acid, hydrogen, carburetted hydrogen, sulphuretted hydrogen and nitrogen. They would seem to favor the passage of the fæcal matter by their distension of the bowel. In some diseases, as hysteria, puerperal fever, inflammation of the bowels, etc., large quantities of gas are accumulated, producing *tympanites* or *meteorism*. The natural color of the fæces is yellow, but in biliary obstruction they become clay-colored and offensive. Again, when the bile is vitiated, or secreted in large quantity, they vary from green to dark brown.

CHAPTER VI.

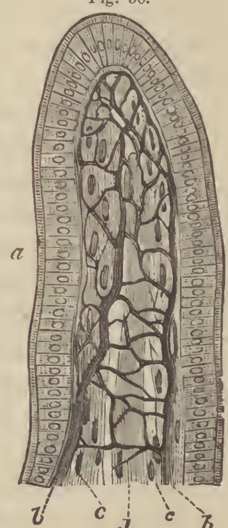
ABSORPTION.

All the tissues of the body are more or less porous, and capable of absorbing fluids brought into contact with them; but the special absorbents are the blood-vessels, villi and lacteals, lymphatic vessels and glands, and *probably* the glandulæ solitariæ.

BLOOD-VESSELS.—The structure and general function of the blood-vessels will be described in the chapter on circulation.

VILLI AND LACTEALS.—The structure of the villi has been already described among the appendages of the mucous membrane, (page 111, Fig. 50.) In consequence of their number and form, they increase greatly the secreting surface of the intestine. They hang out in the nutritious semi-fluid mass contained in the intestinal cavity, like the roots of a tree in its soil, and rapidly imbibe the soluble portions of the food.

Fig. 56.



An intestinal villus; (a) columnar epithelium; (b) capillaries; (c) nonstriated muscular fibre cells; (d) lacteal.

The lacteals commence near the apex of each villus either by a blind extremity, or minute plexus, the precise manner is not known. In structure they resemble the capillaries, having an *outer* structureless or finely fibrillated membrane; and an *inner* endothelial lining. They form a network with close meshes in the submucous areolar tissue, and then pass between the layers of the mesentery towards its root, anastomosing freely with each other, and traversing the mesenteric glands in their way to the right side of the aorta, opposite

the second lumbar vertebra, where they empty themselves, together with the lymphatics from the lower extremities into the receptaculum chyli, or commencement of the thoracic duct. The thoracic duct, which is continued upwards, lies between the aorta and vena azygos major in the thorax; it then passes behind the arch of the aorta, and empties itself into the upper part of the left subclavian vein, close to the internal jugular, its orifice being guarded by two valves. The lacteals, are, however, not a special system of vessels by themselves, but may be considered as a part of the general lymphatic system. Their function is to absorb the chyle.

Lymphatic Vessels and Glands.—These constitute the chief system of absorbents of the body. They are found in nearly every part of the body, except the substance of the brain and spinal cord, eye-ball, cartilage, tendons, membranes of the ovum, placenta, funis, hair, nails and cuticle. They commence either in a closely meshed network, or in irregular lacunar spaces among the tissues termed the *lymph canalicular system.* The latter form a connected system of very irregular branched spaces beneath serous membranes, as the pleura and peritoneum. Recklinghausen has shown that the serous membranes are studded with *stomata* which are the openings of short vertical canals which communicate with the lymph canalicular system. The serous cavities are therefore looked upon as large lymph sinuses, or expansions of the lymph-canalicular system, (page 101.) There are two sets of lymphatics, the *superficial* and *deep*; the former are situated in the superficial fascia, and the latter accompany the deep blood-vessels. Those of the lower extremeties empty into the receptaculum chyli, which is continued upwards through the thoracic duct, to the left subclavian vein, and those of the upper extremities, head and neck, empty by a short trunk into the subclavian vein of the right side.

STRUCTURE.—The lymphatic vessels are remarkable for the transparency of their walls. The larger vessels like the arteries and veins are composed of three coats. 1st, an inner epithelial, (or endothelial) and elastic; 2nd, a middle, muscular and elastic, disposed transversely; and 3rd, an external, areolar and elastic coat. They are also provided with valves like the veins, arranged in pairs, which prevent regurgitation, and assist in the onward flow of the fluid which the vessels contain. The valves are more numerous in the lymphatics than in the veins, and the walls of the vessels are thinner and more transparent. There is no direct communication between the lymph-capillaries and blood-capillaries, as was formerly supposed. The lymphatic vessels may be readily brought into view by injecting them with mercury. The vessels, in their course, pass through certain glandular bodies—the "lymphatic" or "absorbent" glands.

Fig. 57.

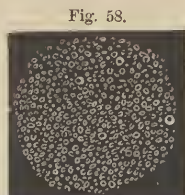
A lymphatic gland and vessels filled with mercury; 1, afferent vessels; 2. efferent vessels; (b) a lymphatic vessel showing the valves; (c) lymph corpuscles, one granular and three treated with acetic acid showing the cell wall and nucleus, also some fine granules and oil globules, (Mascagni) × 400.

LYMPHATIC GLANDS.—The lymphatic glands, among which may be included the *mesenteric glands*, consist of an external layer of connective tissue, and glandular tissue within. From the innner surface of the external layer thin septa or trabeculæ are given off, which penetrate the interior of the gland in every direction, and unite with each other at various points, so that the substance of the gland is divided into numerous spaces or *alveoli*, which communicate with each other. The network is finer in the central or *medullary*, than in the *cortical* portion. These spaces are filled with a network of *retiform* or *adenoid* tissue (p. 71), the interstices of which are filled with lymph corpuscles, and are penetrated like the solitary

glands by a network of capillaries. The lymph corpuscles chiefly occupy the central part of the alveoli, forming with the retiform tissue, nodules and cords, leaving a space in the outer portion for the circulation of the lymph, called the *lymph-path.* Each lymphatic vessel, as it enters the gland, divides into a number of small branches, called the *vasa afferentia* which communicate with the lymph-paths ; other similar twigs form the *vasa efferentia,* which leave the gland in the opposite direction. The lymphatic glands are arranged in chains, in various parts of the body, as in the groin parallel to Poupart's ligament, and along the posterior border of the sterno-cleido-mastoid muscle, etc. They vary in size from a millet seed to a pea. The vessels and glands contain a fluid termed lymph.

LYMPH AND CHYLE.—*Lymph* is a colorless, or pale-yellow, transparent fluid, of a slightly alkaline reaction, and a saline taste. It contains nucleated corpuscles, resembling those found in chyle, but less numerous, which are supposed ultimately to form blood corpuscles. It is spontaneously coagulable when removed from the vessels, owing to the presence of fibrin, which is more abundant in the large than in the small vessels. The albumen is smaller in quantity than in chyle, and there is scarcely any fatty matter. The ingredients of lymph are chiefly the products of the exudation from the capillaries, and the waste of the tissues. It is identical in great part with the liquor sanguinis of the blood.

Fig. 58.



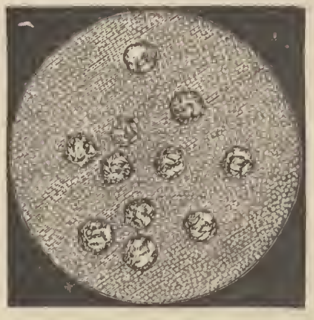
Fat globules of chyle.

Chyle is a whitish, opalescent fluid resembling milk, of an alkaline reaction, and contains numerous fat globules from $\frac{1}{20000}$ to $\frac{1}{30000}$ of an inch (1.25 to .8 mmm) in diameter, which constitute the *molecular base* of chyle. The fat globules are soluble in ether.

As the chyle passes onwards towards the thoracic duct, it becomes more fully elaborated, the quantity of molecules or oil

globules diminish, nucleated cells $\frac{1}{2600}$ to $\frac{1}{3000}$ of an inch, (9.6 to 8.3 mmm) in diameter, called chyle corpuscles, are formed in it, and by the development of fibrin, it acquires the property of coagulating spontaneously. The higher it ascends in the thoracic duct, the more fully is it elaborated, the chyle corpuscles are more numerous, and advanced towards their development into red blood corpuscles, and the clot coagulates more firmly.

Fig. 59.



Molecular base and corpuscles of chyle from the receptaculum chyli of a man.

These two fluids—lymph and chyle—are nearly similar, as will be seen from the following table which is the result of an analysis of the lymph and chyle of a donkey by Owen Rees.

CHEMICAL CONSTITUENTS.—

	Lymph.	Chyle.
Water	96.54	90.24
Albumen	1.20	3.52
Fibrin	0.12	0.37
Fat	A trace.	3.60
Extractive	1.56	1.56
Salt	0.58	0.71
	100.00	100.00

MECHANISM OF ABSORPTION.

Imbibition or osmosis is a physico-chemical process, and occurs in inorganic as well as in dead or living organic bodies. It depends on the force of adhesion between a fluid and a porous solid, by which the fluid is drawn into the interstitial passages of the solid. The fluid chiefly concerned in this process is water, and the various other substances which are taken up in a state of solution, as fibrin, albumen, salts, gases, etc. The process of osmosis in the living body however, is regulated and controlled by the agency of cells, which have the power of choosing and refusing from the materials brought into contact or relation with them.

The *quality of the fluid* influences absorption. If water be brought in contact with the surface of the body, or taken into the stomach, it is readily absorbed, especially in the latter case, because it is brought nearer the blood-vessels; or if a quantity of warm-water is injected into the colon, it is rapidly absorbed and excreted by the kidneys. But if the water contain a quantity of sodium chloride, or any salt in solution, it will be absorbed more slowly, while if a saturated solution be used, the fluid portion of the blood will pass out of the blood-vessels to mingle with it. When the fluid passes from without inwards the process is termed *endosmosis*; when from within outwards, *exosmosis*. The term *osmose* or *osmosis* refers simply to the passage of a fluid in either direction, and is much more convenient. This property of endosmosis and exosmosis may be demonstrated by placing a membranous partition through a vessel of earthenware and placing pure water on one side, and a solution of salt and water on the other. It will be found that the water will pass more rapidly through the membrane to the side containing the salt and water, but that after a time both sides will be equally impregnated with salt. In this case the passage of the water to the salt is called "*endosmosis*," and the more scanty passage of salt to the water "*exosmosis*." The instrument used for measuring the rapidity of osmosis, is called an *endosmometer*. A very good one may be made from a common glass funnel by tying a piece of bladder over the lower end, and fixing a glass tube, open at both ends, in an upright position within the funnel. The instrument is next filled with a solution of salt or sugar, and put in a vessel containing pure water. The water will then pass through the membrane at the bottom of the funnel into the solution by osmosis, and cause the fluid to ascend in the tube, which may have been previously marked, or graduated, by a common file. The height to which the fluid rises in a given time, is a measure of the rapidity of endosmosis over exosmosis. Substances are divided into two classes according

to their facility of osmosis; those which pass through readily, and which are usually crystallizable, are called *crystalloids*, and those which pass with difficulty, *colloids*. The colloids are also distinguished from crystalloids by their inertness as acids or bases.

The *character of the membrane* and its affinity for the fluids influence absorption. If a piece of bladder be placed between alcohol and water, the current is from the water to the alcohol, on account of the greater affinity of the water for this membrane; but if a membrane of India rubber be used, the current is reversed. It is necessary that the membrane should be fresh. If it be in a state of decay, or if it has been dried, it will not produce the desired effect. The position of the membrane causes a variation. In some instances, endosmosis is more rapid when the mucous surface is in contact with the denser solution. In other cases, it is exactly the reverse. The density or laxity, and the thickness or thinness of the membrane, also affect the result for obvious reasons.

Pressure influences absorption. It promotes the transmission of a fluid through a membrane, and the rapidity of osmosis will depend, "*cæteris paribus*," on the degree of pressure employed. Since this promotes the flow in one direction, it also tends to retard the passage of fluids in the opposite direction; for example, when the blood-vessels are distended with blood, as in plethora or inflammation, fluids enter with difficulty from without, while if the tension be removed by venesection, absorption takes place quite readily.

Motion of the fluid in the vessels influences absorption. The motion of the fluid within the vessels promotes absorption, by diminishing the pressure outwards on the walls and allowing the external pressure to predominate, and also by moving the particles onwards, to make room for those which are being absorbed.

Absorption by the Villi and Lacteals.—During the intervals of digestion, the lacteals contain a colorless transparent substance, similar to that which is obtained in other parts of the lymphatic system. If the food consists only of starchy and albuminous substances, very little change is noticed in the character of their contents. But if fat has been taken, the lacteals become filled with a white chyle or "*molecular base*," consisting of minute fat globules and a small quantity of fibrin, albumen, (or albuminose), etc. The presence of chyle in the lacteals is therefore not constant, but occurs during the process of digestion, or as soon as the fatty matters of the food have been disintegrated and emulsified by the intestinal fluids. The absorption of fat from the intestine is not performed exclusively by the lacteals but some of it is taken up by the blood-vessels, for it has been found by Bernard in the blood of the mesenteric veins of the carnivora during digestion. It has also been found in the blood of the portal vein. Fat being a non-osmotic substance, especially when the membrane is moist, a difficulty has been experienced in accounting for its absorption. It has been found, however, that the presence of an alkaline fluid, as bile, mixed with emulsified fat, will facilitate the process of osmosis, and secure the complete absorption of the fatty matter.

The chyle and other fluids are absorbed by the process of osmosis, which is regulated and controlled by the agency of cells. The epithelial cells covering the free surface of the villi are the first active agents in this absorption, for during the process of digestion they are found filled with chyle. They break down, and the fluid passes through the basement membrane by *osmosis (endosmosis)* into the adenoid tissue of the villi being regulated and controlled by the lymphoid cells which are found in its meshes, and in contact with the lacteals. The chyle then comes in direct contact with the lacteals through the coats of which it again passes by osmosis, the process being determined by the cells

which line the interior of the lacteals. The fluid then passes to the receptaculum chyli, and thence through the thoracic duct to the left subclavian vein. Its onward flow is facilitated by the contractile tissue, which is found in the tissue surrounding the lacteals and in the thoracic duct, and it is prevented from regurgitating by the valves which are found in the latter vessel.

ABSORPTION BY THE BLOOD-VESSELS.—That the blood-vessels absorb, has been proved by the experiments of Magendie and Panizza. The latter observer opened the abdomen of a horse, and drew out a portion of the small intestine, eight or nine inches in length, which he enclosed between two ligatures. He then ligated the mesenteric vein, and made an opening behind the ligature, in order to allow the blood brought by the artery to pass out. An opening was also made in the intestine, through which was introduced some hydrocyanic acid, and almost immediately afterwards, it was detected in the blood which flowed from the opening in the vein. The above experiment was varied by simply compressing the vein, and introducing hydrocyanic acid in the intestine. In this case no effect was produced on the animal while compression was maintained, but as soon as the pressure was removed, symptoms of poisoning by hydrocyanic acid showed themselves. The rapidity with which the blood-vessels absorb certain substances may be seen in the administration of alcoholic and other soluble substances by the stomach, and also the hypodermic injection of morphine and other alkaloids. The blood-vessels not only perform an active part in the general absorption of fluids in various parts of the body, but are also specially engaged in the absorption of the alimentary fluids of the intestine. The albuminous and starchy portions (and even fatty matters) of the food are absorbed by them from the mucous surface of the stomach and small intestine, in the form of albuminose and glucose. The substances taken up by the veins are thence conveyed by the portal system to the

liver, where some of them are acted upon by that organ in the production of bile, sugar, fat, etc., some of which are carried back into the alimentary system, and others are thrown into the general circulation. In the process of absorption, the substances pass through the basement membrane by osmosis, this process being regulated by the action of the cells, similar to that which takes place in the lacteals.

ABSORPTION BY THE LYMPHATICS.—That the lymphatics absorb, is perhaps best shown by the phenomena of disease; for example, the virus of syphilis is frequently carried from the chancre on the penis, to the glands in the groin, giving rise to bubo, and the matter from the abscess is capable of imparting the disease to other individuals. The glands of the axilla become enlarged and inflamed, in consequence of a poisoned wound of the hand or arm, or in erysipelas. Absorption takes place in the same way, and on the same principle, as in the lacteals and veins. In some animals, as birds and reptiles, the movement of the lymph is facilitated by the action of certain muscular sacs, called *lymph hearts*. The function of the lymphatic vessels is to absorb the ingredients of the lymph derived from the metamorphosis of the tissues, and to return it into the general circulation, in order to subserve some further purpose in the animal economy, or to be eliminated by the process of excretion. They also convey back the superfluous parts of the material brought by the blood-vessels for the supply of the tissues. The effete matters are not all absorbed by these vessels, for carbonic acid seems to enter the capillaries in a direct manner through their walls, since it is found in greater quantity in venous than arterial blood. The lymphatic glands are engaged in the process of elaborating the lymph in its passage through them.

THE *Glandulæ Solitariæ* have been already described (page 111). They are regarded as the first row of mesenteric glands situated in the walls of the intestines.

CHAPTER VII.

BLOOD.

THIS fluid is prepared from the food by the proces of digestion and assimilation, and is constantly circulating through the vessels, during life. It supplies the material from which the tissues are built up and nourished; it contains the substance used in the combustive process, and also contains the effete particles which result from the disintegration of the tissues. The elements found in the blood may be divided into four classes, as follows :—

1st. The *elaborative* elements, as red and white corpuscles.

2nd. The *histogenetic* elements, as albumen, and fat. (Fat is used to build up the adipose and nerve tissues.)

3rd. The *calorific* elements, as sugar (or glucose) and fats.

4th. The *depuritic* elements, as lactic, uric, hippuric, and carbonic acids, urea, creatine, volatile fat acids, odorous substances, salts, and water.

QUANTITY.—It is very difficult to determine the exact quantity of blood in the human body; but from various experiments, it has been ascertained by approximation, that the quantity of blood in a human body weighing 144 lbs. would be about 16 or 18 lbs., or as 1 to 8 or 10.

PHYSICAL CHARACTER OF THE BLOOD.

The blood, as it flows from the vessels, appears to be a homogenous, red fluid, of a slightly alkaline reaction, and heavier than water. The odor resembles the perspiration, or the breath of the animal. The temperature is about 100° F. The color of arterial blood is bright scarlet, and that of venous blood dark purple; but disease of the lungs, heart or

kidney, may cause the whole mass to assume a venous hue, owing to the circulation of carbonic acid and other impurities in it; or it may assume an arterial hue when the animal breathes pure oxygen. It is also stated by Dr. Davy that in warm climates the blood is venous in its character. This is due to the high temperature, which reduces the excretion of carbonic acid, and is a fact of very great practical importance to the physician. The inhalation of chloroform or ether produces a venous condition, by interfering with the function of respiration.

The *specific gravity* of the blood varies from 1050 to 1059, the average being about 1055. Any substance which will modify the relation between the solids and fluids will change the specific gravity. For example, it may be diminished by the introduction of water into the system, whilst, on the other hand, it may be increased by the administration of drastic purgatives. In anemia, the specific gravity may be increased by good liberal diet, and iron. The specific gravity of the corpuscles (solids) is 1088, the liquor sanguinis (fluids) 1028.

MICROSCOPICAL APPEARANCE OF THE BLOOD.

Blood, when examined by the microscope, when still in the vessels, as in the frog's foot, or bat's wing is seen to consist of a solid and a liquid portion; the former includes the *red and white corpuscles,* the latter, the *liquor sanguinis,* or plasma. On the other hand, when the blood has been drawn from the body, and allowed to stand, it coagulates or separates into two portions—the *crassamentum,* or clot, and the *serum.* This coagulation depends on the presence of fibrin, which coagulates spontaneously, and forms a network of fibres, in the meshes of which are included the red and white corpuscles. The clot then contracts, and squeezes out the serum. The crassamentum, or clot, therefore consists of the fibrin and corpuscles; and the serum contains

the albumen, salts and water. Blood in the living vessels, consists of

SOLID.	LIQUID.	
Red and White Corpuscles.	Fibrin........ Albumen...... Salts..:...... Water	Liquor Sanguinis, or Plasma.

Blood out of the body consists of

SOLID.		LIQUID.	
Red and White Corpuscles Fibrin..................	Clot.	Albumen...... Salts.......... Water.........	Serum.

Blood Corpuscles.—The human *red* blood corpuscles are circular or rounded biconcave discs, in the centre of which are seen bright or dark spots according as the microscope is within or beyond focus. These spots which have been mistaken, for nuclei (structures which these corpuscles do not posses at maturity), are the result of the refraction of light. The form of the disc may be changed by any agent which modifies the specific gravity of the blood, or interferes with the circulation. For example, water is readily absorbed by the corpuscle, causing it to become oval, then rounded, and finally to burst. Gulliver mentions the case of oxen having died from drinking too much water; and from the bursting of the corpuscles, and the liberation of the hemoglobine, the arteries were stained, so as to give rise to the supposition of arteritis. In anemia and Bright's disease they become oval, and in the latter case granular. When the amount of fluid is diminished, or solids increased, as in plethora, the corpuscles become strongly biconcave and ragged on the

Fig 60.

(a) Human red blood corpuscles; (b) one seen edgewise; (c) in rouleaux; (d, d) white corpuscles; (e) white corpuscle undergoing amæboid change of shape; (f) red blood corpuscles dried shrunken and crenated; (g) red corpuscles as seen within the focus of the microscope; (h) the same as seen beyond the focus.

borders. The inhalation of gases also produces a marked change in their shape. When carbonic acid is inhaled they become rounded, and are again rendered biconcave by breathing pure air or oxygen gas. When chloroform is inhaled they become rounded and serrated. Ether produces an irregular outline, and the administration of alcohol renders them oval and indented on one side. A solution of sodium chloride added to the blood, produces a prickly condition of the surface of the corpuscles, like the fruit of a horse-chestnut. When acetic acid is added, they become globular and pale, and alkalies cause them to swell up and disappear. Tannin (2 per cent. solution) produces a small projection or button on some point of the circumference, which disappears again on the addition of acetic acid. The corpuscles may be changed in shape during circulation. In the capillaries, they sometimes become elongated, twisted or bent, in order to accommodate themselves to the narrow curved channels through which they have to pass. They consist of homogeneous masses of germinal matter or *stroma* infiltrated by a red coloring matter, termed *hemoglobine*, and have no distinctive cell wall.

The *size* of the red blood corpuscles varies in the human subject from $\frac{1}{3000}$ to $\frac{1}{4000}$ of an inch (8.3 to 6.2 mmm) in diameter, the average being about $\frac{1}{3500}$ (7.1 mmm) and the thickness about $\frac{1}{10000}$ (2.5 mm.) The size of the corpuscles bears no relation to the size of the animal, *e. g.*, those of the mouse tribe are larger than those of the deer, as will be seen from the following table:

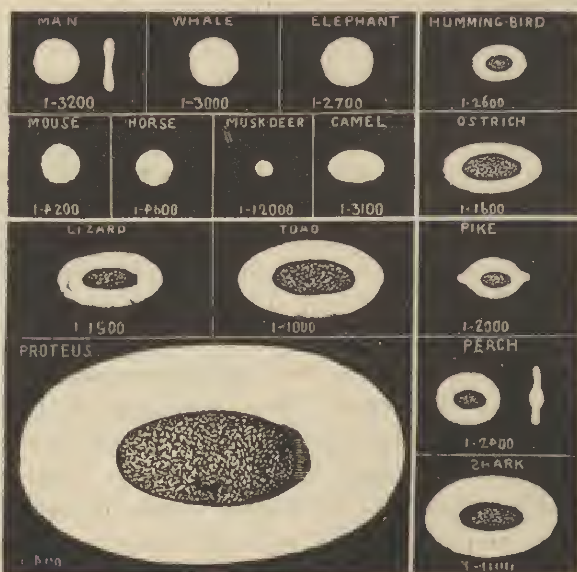
Man......	$\frac{1}{3500}$ (7.1 mmm)	Mouse....	$\frac{1}{3800}$ (6.5 mmm)
Ape.......	$\frac{1}{3500}$ (7.1 ")	Cat.......	$\frac{1}{4400}$ (5.7 ")
Horse....	$\frac{1}{4600}$ (5.4 ")	Fox.......	$\frac{1}{4100}$ (6.1 ")
Ox........	$\frac{1}{4200}$ (6.0 ")	Wolf	$\frac{1}{3800}$ (7.0 ")
Sheep....	$\frac{1}{6300}$ (4.0 ")	Elephant .	$\frac{1}{2700}$ (9.2 ")
Goat......	$\frac{1}{6300}$ (4 0 ")	Red Deer.	$\frac{1}{5000}$ (5.0 ")
Dog.......	$\frac{1}{3500}$ (7.1 ")	Musk Deer	$\frac{1}{12000}$ (2.0 ")
Rabbit ...	$\frac{1}{3600}$ (7.0 ")	Sloth......	$\frac{1}{2800}$ (9.0 ")

In all of the above, the form and appearance of the corpuscles are the same, although they vary much in size. The

elephant, and sloth (*Bradypus didactylus*) are the only species in which the corpuscles are known to be larger than in man. In the camel tribe (camel dromedary lama) they are oval in shape, but do not possess a nucleus. In all the oviparous vertebrata, as birds, reptiles, and fishes, the corpuscles are of a large size, oval in shape, and contain granular nuclei. The nuclei may be distinctly seen on the addition of acetic acid, which clears up the outer portion. The corpuscle of the frog is from $\frac{1}{1000}$ to $\frac{1}{1200}$ of an inch (25 to 21 mmm) in diameter,[3]

Fig. 61.

Mammals. Birds.



Reptiles. Fishes.

Typical characters of the red-blood corpuscles in the main divisions of the Vertebrata (modified from Gulliver.) The average diameter in the longest axis is given in each case.

COLOR.—In a single stratum of red corpuscles no color is observed, but when two or three are superimposed upon one another, a reddish tint becomes apparent. The color depends partly on the shape of the corpuscles, but chiefly on

the hemoglobine they contain. They also have a tendency to adhere by their concave surfaces in the form of *rouleaux.* (Fig. 60, c). This is peculiar to the red corpuscles, and is very much increased in inflammation. If any of the salines be added to the blood, this peculiar tendency is in a measure neutralized.

WHITE CORPUSCLES.—These are so named on account of their white, or colorless appearance. They have a circular outline, appear granular within, and are tolerably uniform in size, theird iameter being about $\frac{1}{3000}$ of an inch (8. mmm.) in warm-bloods, and $\frac{1}{2500}$ (10 mmm.) in reptiles. In some of them a nucleus may be distinctly seen on the addition of acetic acid; in others the nucleus appears to be broken up, so as to give the cell a granular appearance, (Fig. 60, d). They are more highly refractive than the red under the microscope, and are generally observed in or near the margin of the field, while the red are grouped together in the central part. When examined in the circulating blood of a frog's foot, they are seen to occupy the exterior of the current, and adhere more or less to the walls of the vessels, or appear to pass from the centre to the walls and back again. The proportion of white to red corpuscles in man, is about one to 400 or 500; but in inflammation it may be one to ten. In certain diseases as anemia, leucocythæmia, etc., the white corpuscles are relatively increased. In the oviparous vertebrata the proportion is higher than in man, being about one to sixteen; while in one of the vertebrata (amphioxus) the red corpuscles are entirely absent. In the invertebrate series, on the other hand, the corpuscles are almost invariably white, and hence the so-called white blood of this class of animals. The white corpuscles have the power of spontaneously changing their shape, and of moving in certain directions, closely resembling those of the amœba, (Fig. 12), and hence termed *amœboid* movements, (Fig. 60, e.) This is due to the contractile property of the protoplasm. The amœboid movements are

arrested by the addition of water or acetic acid. The white corpuscles are reproduced by the process of fission. The blood also contains *granules* or *molecules*, $\frac{1}{8000}$ of an inch, (3. mmm.) in diameter, similar to those found in lymph and chyle, some of them fatty, and others probably albuminous.

Origin of the Corpuscles.—The earliest blood corpuscles are formed from the primordial cells in the vascular tract. The embryonic heart and aorta are formed by the arrangement of masses of the primitive cells, or germinal vesicles, of the mucous or vegetative layer, in the position, form, and thickness of the developing vessels respectively. The external layer of cells is converted into the walls of the vessels, while those in the interior form the first blood corpuscles. The primordial, or primitive vesicles, are large, colorless, spherical cells, each containing a nucleus, nucleolus, granular matter, and fat globules. These cells, gradually clear up, so as to bring into view the nucleus, become reduced in size, and develope the coloring matter (hemoglobine) as they pass into the form of red corpuscles. The blood corpuscles of the human embryo thus formed are circular, disc-shaped, full colored, and, on an average, about $\frac{1}{2500}$ of an inch (10 mmm.) in diameter. They each contain a nucleus (and in some cases two), about $\frac{1}{5000}$ of an inch (5 mmm.) in diameter, and slightly granular. They are reproduced by the process of multiplication by subdivision, or fission.

When the liver begins to be formed this multiplication of blood corpuscles in the mass of blood ceases, according to Kôlliker, and a new production of colorless nucleated cells takes place in the vessels of the liver. These nucleated cells undergo a gradual change into red corpuscles, similar to those of the first brood.

After birth, when the lymph and chyle corpuscles are thrown into the current of blood, they are developed into red blood corpuscles, so as to supersede those formed as

above described. This is evidenced—*First* by the formation of color, while the chyle and lymph are passing through the thoracic duct, due to the development of hemoglobine. *Secondly*, by the presence of corpuscles, which appear to be intermediate stages of development between the lymph corpuscles, and the nucleated red corpuscles in the blood of oviparous vertebrata. *Thirdly*, by the progressive transition from lymph or white blood, to red blood, which may be observed in the ascending scale of animal life.

DEVELOPMENT FROM CHYLE AND LYMPH CORPUSCLES.—Kôlliker and Paget regard the *red blood corpuscles* as being formed from the smaller of the lymph and chyle corpuscles by a gradual progressive metamorphosis; while Wharton Jones and Huxley maintain that they are formed from the nuclei alone, the outer portion of the cells disappearing in the change. The weight of authority, however, appears to favor the former opinion. The change from chyle and lymph corpuscles to red blood corpuscles, takes place as follows:—The chyle and lymph corpuscles are at first nucleated cells, the nuclei of which are generally more or less obscured by the granular matter which surrounds them, (Fig. 59.) They vary in size from $\frac{1}{2500}$ to $\frac{1}{3000}$ of an inch, (10 to 8.1 mmm.) in diameter. The granular matter clears up, and the nuclei disappear. They then become flattened or biconcave, contraction and consolidation of the cells take place, which reduce their size to a certain extent, and hemoglobine is developed.

The *white corpuscles* are also developed from chyle and lymph corpuscles. Lymph corpuscles are formed in the lymphatic glands, spleen, adenoid tissue, and medulla of bone. The red and white corpuscles are regarded by some as two distinct and complete forms, neither being capable of metamorphosis into the other, and each having its own specific purpose to subserve in the animal economy; the greater number of chyle and lymph corpuscles proceeding to the formation of red corpuscles, while a few of them are

developed into the white corpuscles of the blood. The argument in favor of this theory is, that the white corpuscles have been found in the blood in a state of decay, thus showing that they were not destined to proceed to a higher development. By others they are regarded as an early or embryonic condition of the red corpuscles, or an intermediate stage of metamorphosis between the chyle and lymph corpuscles, and the red corpuscles. The latter view is supported by the following arguments:

1st, The colorless corpuscles are intermediate in shape and general appearance.

2nd. They are increased under circumstances unfavorable to normal changes, as in inflammation, or in persons of weak health, as in anemia, leucocythæmia, and in the tubercular diathesis.

The red and white corpuscles are supposed by some to be developed directly from the plasma of the blood in which they float, by the ordinary process of cytogenesis. Blood corpuscles, like other cells, have their period of growth, maturity and decay, and while some are undergoing the process of disintegration, others are rising up to take their places. They are, no doubt, formed very rapidly, as is evidenced in their rapid formation after great hemorrhage, and their growth and development may be facilitated by the administration of iron, and a liberal diet. When the corpuscles are beginning to decay, they generally present at first a granular appearance; after a little they break down, and the contents disappear. Many of them may be observed in a granular state in phthisis, albuminuria, and septic poisoning.

CHEMICAL AND STRUCTURAL CHARACTERS OF THE BLOOD.

Chemical Composition of the Blood.—The average proportion of the constituents of the blood in 1000 parts is as follows:—

Water		784.0
Albumen (of serum)		70.0
Fibrin		2.2
Red corpuscles (dry)		130.0
Fatty matters		1.4
Inorganic Salts :	Sodium and Potassium Chlorides	3.95
	Sodium Phosphate, Carbonate and Sulphate	1.30
	Calcium and Magnesium Phosphates	0.25
	Iron Oxide and Phosphate	0.5
Odoriferous and coloring matter, glucose, gases, creatine, urea, and other extractive matters		6.40
		1000.

These proportions are subject to considerable variation, even in health, depending on diet, mode of living, etc. The proportion of the various ingredients may be determined as follows:—The blood, as it flows from the vein, is received into two vessels of equal size, the first and last portions of the whole amount into the first, and the second and third portions into the second vessel, in order that the two quantities may be nearly alike, and then weighed. The blood in the first vessel is allowed to coagulate; that in the second is whipped with a bundle of twigs, to separate the fibrin, which is then washed with water—to remove the salts, with alcohol—to remove any coloring matter, and with ether—to remove any fats. It is then weighed. The clot which has formed in the first vessel is then taken out, and after the serum has drained away, it should be weighed. From the weight of the clot subtract the weight of the fibrin obtained from the second vessel, and this will give the weight of the corpuscles. The amount of albumen may be obtained by precipitating it from the serum, filtering and weighing. In this way it may be ascertained that in 100 parts blood, about 78 parts are fluid, and 22 parts solid material. In the latter, there are 13 parts corpuscles, 7 parts albumen, $\frac{1}{4}$ part fibrin, the salts, etc., making up the balance. In ordinary analysis, the corpuscles are estimated at about 13 per cent. by weight, of the entire blood. This refers, of course, to the dry corpuscles, from which the water has been removed. But it is easily seen, by a

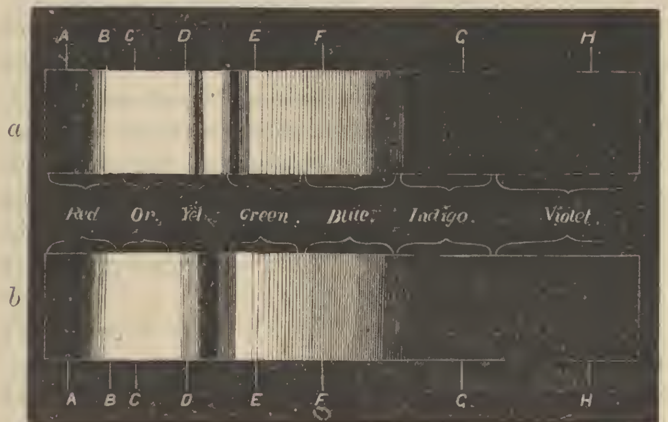
microscopic examination, that the corpuscles, in their natural moist condition in the blood, constitute fully one-half of the entire mass; hence the discrepancy in the analysis of different observers. Lehmann and Schmidt put the *moist* corpuscles at 512 parts in 1000, or about four times the weight as given above. Three fourths of their weight, consist of water.

The red blood corpuscles are composed of a transparent homogenous substance called the *stroma,* in which the *hemoglobine* is infiltrated. The stroma is tough and elastic, and consists of globuline, protagon, fatty matters, cholesterine, and salts. The most important of these is the *globuline.* It is a semi-fluid substance, belongs to the albuminous compounds, and is formed from albumen. It is soluble in water, but not in the liquor sanguinis or fluid plasma of the blood, and is readily acted on by acetic acid, causing the corpuscles to swell out and finally burst. It coagulates completely at 200° F.

Hemoglobine is a kind of pigment matter which is found in the red blood corpuscles, mingled with the stroma. It is more abundant than any other ingredient of the corpuscles. It belongs to the albuminous compounds, being developed from albumen or fibrin, and consists of C_{54} H_{7} N_{16} O_{21} $S_{.6}$ $Fe_{.4}$ the latter of which is an essential ingredient. It is soluble in water, dilute alcohol and alkalies, but is insoluble in ether, strong alcohol and oils. It crystalizes in rhombic, or hexagonal plates or prisms, forming the so-called *blood crystals.* Although a *crystalloid,* and soluble in water, it is not diffusible, *i.e.,* it does not pass through the pores of an animal membrane. When heated, it is decomposed into *globuline* and *hematine.* The distinguishing characteristic of hemoglobine is its strong affinity for oxygen, forming oxy-hemoglobine, which has a *scarlet* color; this readily parts with its oxygen again in the presence of reducing agents, and assumes a *purple* hue. On these qualities depend its most important physiological

properties, viz., as a carrier of oxygen. This also explains the scarlet color of arterial blood, and the purple tint of venous. It was formerly supposed that the scarlet color of the blood was produced by the oxygen rendering the corpuscles biconcave, and the venous condition by carbonic acid which made them biconvex or rounded.

Fig's. 62 and 63.



a. Spectrum of oxidized hemoglobine. *b.* Spectrum of deoxidized hemoglobine.

The two varieties of hemoglobine may be readily distinguished by the *spectroscope.* A solution of oxy-hemoglobine or diluted arterial blood, presents two absorption bands in the *spectrum,* between the lines D and E, one in the yellow and the other at the commencement of the green, (Fig. 62, a). The former is narrow and well defined, the latter is broader and not so well marked. The spectrum of deoxidized hemoglobine on the other hand, presents a single absorption band intermediate in position between the other two, (Fig. 63, b). When from any cause the red corpuscles are broken down, the hemoglobine is set free, and stains the coats of the vessels, so as to give rise to an appearance resembling arteritis. Rupture of the corpuscles may take place from drinking too much water, or in low forms of disease, as in typhoid fever, purpura hemorrhagica, etc.

Distinction between Human and Animal Blood.—It is sometimes of the utmost importance in medical investigations to distinguish between human blood and the blood of animals. In a fluid, or blood stain, when the corpuscles have been dissolved or destroyed, the presence of blood may still be determined by the spectrum of hemoglobine, but the distinction between human and animal blood cannot thus be made. It is only by the use of the microscope that this can be determined. If the blood stain be found to contain oval nucleated corpuscles, it cannot be human blood, but that of a fowl, reptile or fish. If, on the other hand, the corpuscles are circular and without nuclei, then it will be impossible to say whether it is human blood, or the blood of some animal, as the cow, sheep, ape, dog, etc., whose corpuscles are nearly of the same size as the human.

DIFFERENCE BETWEEN ARTERIAL AND VENOUS BLOOD.

Arterial and venous blood differ from each other in *general composition* and *color*. The analysis which has already been given is of venous blood. In arterial blood the quantity of solid constituents of the corpuscles is less, but relatively they contain more hemoglobine and salts, and less fat. It also contains more oxygen and less carbonic acid. The liquor sanguinis is richer in fibrin, contains more water, and less albumen. The fatty matters of the serum are diminished, and the extractive matters increased. The phosphorus which exists in the venous blood, is converted at the lungs into phosphoric acid, which then unites with the alkalies of the serum, as lime, potassa, soda, magnesia, etc., forming phosphates. Phosphorus is used in the building up of nerve and bone tissue.

Blood of the Portal, Renal and Hepatic Veins.—Blood drawn from different parts of the arterial system of the same animal is nearly always the same; but great variations exist in the composition of the blood in the different parts of the venous system. The portal vein contains blood

derived from the gastric, mesenteric and splenic veins. During digestion, the blood of the *gastric* and *mesenteric* veins is much diluted, and contains the soluble alimentary substances taken up from the stomach and small intestine, as sugar (glucose), albuminose, etc. The fibrin also found in these vessels is less perfectly elaborated than in the blood in general, and liquifies soon after coagulation. On the other hand, the blood of the *splenic* vein shows a diminution of the red corpuscles, an increase of the white corpuscles, and an increase of the albumen. The fibrin is also increased, but like that of the gastric and mesenteric veins it is not fully elaborated, coagulates imperfectly, and liquifies soon afterwards. The blood of the *renal veins* is the *purest in the body*, having, subsequently to its purification in the lungs, been deprived of other impurities by the kidneys, such as urea, creatine, salts, etc. It contains less water, the albumen is neutral in reaction, and the fibrin is scanty and will not coagulate, (Brown Sequard.) The blood of the *hepatic* veins contains an increased amount of sugar and fat, which are formed during the passage of the blood through the liver. It also contains less water, albumen and salts, and more corpuscles and extractive matter, than that of the portal vein.

Gases.—There is a remarkable difference in the amount of *gases* which arterial and venous blood respectively contain. The former contains from 16 to 20 per cent., by volume, of oxygen, while the latter contains about 12. The quantity of carbonic acid, on the other hand, is from 30 to 35 per cent. in arterial, and from 40 to 50 per cent. in venous blood. The quantity of nitrogen varies from 1 to 2 in arterial and venous blood respectively. There are also traces of ammonia. The difference between the amount of oxygen and carbonic acid respectively in arterial and venous blood, confirms the idea that an exchange of oxygen for carbonic acid takes place in the system, and an exchange of carbonic acid for oxygen in the lungs. The red

corpuscles carry oxygen from the lungs to the tissues, and return carbonic acid for elimination. The serum also possesses the property of absorbing or dissolving carbonic acid. A certain part of the oxygen is used directly in the formation of fibrin, from albumen. The proper development of fibrin does not take place when the due aëration of the blood is interfered with, as in double pneumonia, in which case it is very much diminished. The presence of oxygen seems to be essential to the production of fibrin, and it has been shown by experiments on rabbits, that when pure oxygen is breathed the quantity of fibrin is very much increased.

Dr. Gairdner examined the blood of six healthy rabbits, and found it to consist as follows, in 1,000 parts:

Fibrin	1.65
Corpuscles	82.35
Albumen	46.30

He also examined the blood of three of these, which had been exposed to an atmosphere of pure oxygen for half an hour, and found it to contain as follows:

Fibrin	2.40
Corpuscles	69.56
Albumen	40.23

Another of these animals was exposed to the action of an electro-magnetic current passed between the chest and spine, which produced a great acceleration of the respiratory movements, and the blood was found to contain 2.9 parts of fibrin in a thousand. Although the corpuscles appear to be very different in the two tables, yet their relative amount in proportion to the albumen is almost exactly the same in both cases.

COLOR.—The difference in *color* between arterial and venous blood, is due to the hemoglobine which the red corpuscles contain and the change of color produced in it by the influence of oxygen. It is also partly due to the change of shape of the corpuscles. They are biconcave in arterial blood, and rounded in venous. The former is produced by the in-

fluence of oxygen; but it may also be occasioned by contact with some of the salts in solution, without any direct exposure to oxygen. The blood is darkened in color by whatever tends to expand the corpuscles, so as to render them rounded, whilst it is brightened by whatever tends to render them biconcave. For example, arterial blood is darkened by the addition of water, which swells out the corpuscles and deprives them of some of their coloring matter.

CONDITIONS WHICH INFLUENCE THE CHARACTER OF THE BLOOD.

INFLUENCE OF VENESECTION.—It has been found by experiment that, in bleeding, the corpuscles suffer most; the fibrin is increased, and the water taken away is soon replaced by transudation from the tissues, so that the specific gravity is diminished, as will be seen from the following table, the result of the analysis of the blood of ten patients, by Becquerel and Rodier:

	1st Bleeding.	2nd Bleeding.	3rd Bleeding.
Specific gravity of defibrinated blood	1056.0	1053.0	1049.6
Specific gravity of Serum	1028.8	1026.3	1025.6
Water	793.0	807.7	823.1
Corpuscles	129.2	116.3	99.4
Albumen	65.0	63.7	64.6
Fibrin	3.5	3.8	3.4
Extractive and Salts	7.7	6.9	8.0
Fatty Matters	1.6	1.6	1.5
	1000.0	1000.0	1000.0

From the above it will be seen that the corpuscles are notably diminished, and that bleeding has no effect whatever in diminishing the amount of fibrin. Fibrin is increased in all inflammatory diseases, and the most copious venesection is unable to check it, but rather increases it. The following table gives the result of bleeding, in a case of rheumatism, from Christison:

Water	844
Solids of Serum	93
Corpuscles	57
Fibrin	4

INFLUENCE OF STARVATION ON THE BLOOD.—This is somewhat similar to prolonged venesection. The following tables show the result of bleeeding upon a well-fed dog; and also the same, in a state of starvation. (Todd and Bowman):

		Number of Bleedings.			
		1st.	2nd.	3rd.	4th.
While being fed.	Water..........	783.79	810.89	815.18	813.04
	Corpuscles.......	142.85	113.54	110.58	106.95
	Solids of Serum.	70.94	70.85	69.92	76.01
	Fibrin..........	2.42	4.72	4.34	3.99

After these bleedings, the animal was allowed to recover, and was well fed for about three weeks. He was then starved for about four days, being allowed nothing but water, and bled each day, with the following result:

		Number of Bleedings.			
		1st.	2nd.	3rd.	4th.
While being starved.	Water..........	804.40	805.44	838.30	849.84
	Corpuscles......	121.08	119.15	87.98	74.21
	Solids of Serum.	72.61	71.46	68.46	71.62
	Fibrin..........	1.91	3.95	5.26	5.13

In the latter case, the diminution of the corpuscles is more marked than in the former; and it will be observed that the corpuscles had not entirely recovered from the effects of the first bleeding. It will also be observed that, in both cases, there is at first an increase in the fibrin, and afterwards a diminution—the latter being caused by the diminution of the red corpuscles, and consequent non-development of the fibrin.

INFLUENCE OF IRON AND FLESH DIET ON THE BLOOD— The quantity of blood corpuscles may be increased by the administration of iron and flesh diet. Fresh beef is the best diet for this purpose. It contains the most appropriate materials for nutrition, and is comparatively easy of digestion. The essence of beef, or beef tea, is still better, especially when the patient is very feeble, and the stomach unable to digest solid food. In anemia, the corpuscles have been increased from forty to sixty, and even ninety in a thousand, in a few weeks, by this mode of treatment.

INFLUENCE OF AGE ON THE BLOOD.—During the latter part of fœtal life, the solids of the blood, especially the red and white corpuscles, are increased, and remain high for a short time after birth. They then gradually diminish until puberty, when they are again increased, and remain so during the most vigorous period of adult life, after which they begin to decline, as old age advances. The object of these changes in the increase of solids, is to fit the blood more fully for the nourishment and growth of the body at these important periods, viz; immediately after birth, at puberty, and during the period of ovulation in the female, and the corresponding period in the male.

INFLUENCE OF SEX ON THE BLOOD.—The solid elements of the blood, especially the red corpuscles, are increased in the male. In *pregnancy*, the blood has a lower *sp. gr.* than the average, owing to the deficiency of red corpuscles. On the other hand, the white corpuscles and fibrin are increased, the latter especially during the last three months. This may be considered a wise provision of nature to favor the formation of clots in the mouths of the open vessels after parturition and the separation of the placenta, and to prevent post-partum hæmorrhage.

INFLUENCE OF DISEASE ON THE BLOOD.—It will be seen from the following table that the principal constituents of the blood may vary much, in health, in different persons; and in the same person, at different times. This may be due to various causes, as the kind or quality of the food, habits, amount of exercise, etc. According to Andral, the variations may be as follows:

Fibrin	from	2	to	3½	parts per	thousand.
Corpuscles	"	110	to	152	"	"
Solids of Serum	"	72	to	88	"	"
Water	"	760	to	815	"	"
etc., etc.						

In estimating the quantity of *fibrin* in the blood in diseased conditions, it should always be borne in mind that it may contain a number of white corpuscles. These are very

difficult to separate, and although not very numerous in a state of health, yet in many diseases, as inflammation, anemia, leucocythæmia, etc., they are so much increased as to add materially to the amount of fibrin. There is found to be an invariable increase of fibrin in all acute inflammatory affections of a sthenic kind. This augmentation is so constant, that if more than five parts of fibrin in a thousand be found in the course of any disease, it may be positively affirmed that some local inflammation is present. The maximum proportion of fibrin in inflammation may be stated at about 13.3 (acute rheumatism), the minimum 5, and the average about 7 parts in a thousand. Even in anemia and chlorosis it rises to 6 or 7 in inflammation. In phthisis also, there is an increase, notwithstanding the deterioration of the blood. It is, no doubt, due to the local inflammation going on around the tubercles. In single pneumonia the fibrin has been found as high as 10.7; in acute rheumatism, 13.3. It is slightly increased in all the exanthemata. It is also increased in leucocythæmia. The increase in the quantity of fibrin does not depend upon the febrile condition present in inflammation, but upon the inflammation itself. For example, in continued fever it is lower than in health, but if local inflammation arise in the course of the disease, the fibrin is at once increased. In simple continued fever it has been found as low as 1.6. In typhoid fever it may vary from 3.7 to 0.9, and in some cases the blood shows no disposition to coagulate, the fibrin either being entirely deficient, or very much lowered in vitality. In double pneumonia it is as low as 0.9, due to the imperfect aëration of the blood. In scurvy it is sometimes increased, and sometimes diminished. In cholera the serum is first diminished next the albumen, and afterwards the fibrin. The vomited matters, and substances passed by the bowels are coagulable by heat and nitric acid. The fibrin is diminished in apoplexy, due probably to the arrest of nerve force. In purpura hemorrhagica it is 0.9, and

sometimes entirely deficient. One of the effects of a diminution in the proportion of fibrin is a tendency to the occurrence of hemorrhage from slight causes, which is difficult to arrest.

The amount of *red corpuscles* is subject to greater variation within the limits of health than the fibrin. In plethora they may be increased to 180 or 190. Plethoric persons are not on that account more liable to inflammation; but they are very prone to congestion, especially of the brain, and apoplexy. This condition may be easily remedied by venesection. The number of corpuscles may be reduced from 180 to 144, or from 60 to 48 in one bleeding. In anemia, on the other hand, the corpuscles are diminished, in some cases as low as 27 in a thousand, but they may be rapidly increased by appropriate treatment. They have been increased in some instances from 40 to 60, and even 90, in three or four weeks. In diabetes mellitus, Bright's disease, disease of the heart, lead poisoning, tuberculosis, cancer, scurvy, leucocythæmia, etc., they are materially diminished, and often assume a granular appearance.

The *colorless corpuscles* are said to be increased in inflammation, but it is by no means constant. In the disease first pointed out by Dr. John Hughes Bennett, of Edinburgh, and termed by him leucocythæmia, they are largely increased. In this disease the specific gravity of the blood is low, and the fibrin is invariably increased.

The quantity of *albumen* seems to vary very little. It is reduced in cholera, albuminuria, etc., so that the entire solids of the serum have been found in some cases as low as 52 in a thousand. The diminution in the amount of the albumen in the serum, in albuminuria, is exactly proportioned to the quantity found in the urine.

The *fatty matters* are very much increased in some instances, so as to give the serum a milky appearance, as for example in tuberculosis, Bright's disease, hepatitis, dropsy,

10

etc., and also during lactation in the female. Very little is known regarding the variations of the *alkaline salts* in disease.

The proportion of *water* varies according to the amount of solids, being increased when the solids are diminished, and *vice versa.* In cholera, however, the drain is very great, and the reduction of the watery portion is most marked.

Blood Poisons.—Substances which should be excreted from the body, as carbonic acid, urea, bile, etc., may be retained in the circulating current, and be attended with serious and sometimes fatal results. The most serious cases of blood poisoning, however, are those in which the poison is introduced from without, producing fermentation of the mass of blood, and destroying its vitality, as the poison of malignant pustule, typhoid, glanders, venom of serpents, etc.

COAGULATION AND VITAL PROPERTIES OF THE BLOOD.

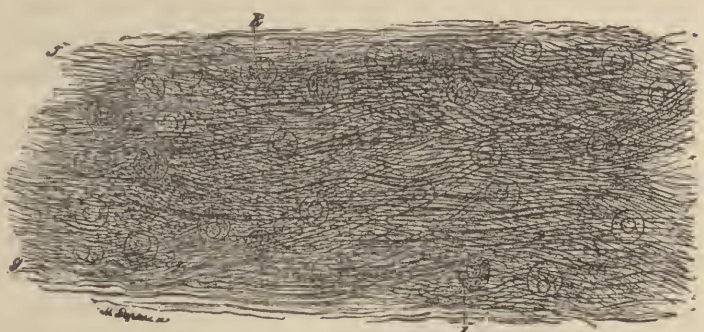
The blood is the pabulum of all the tissues of the body. It is a living fluid, which possesses the power of reproducing and maintaining itself, and contains all the elements necessary for the supply of the tissues, and nothing deleterious or poisonous; for the presence of pus, urea, venom of serpents, or septic poisons, would be alike destructive to the vitality of the blood, and also the tissues. It has a certain amount of viscidity, which seems necessary to its free circulation through the capillaries. Besides, it is observed that, when from any cause the albumen and fibrin are diminished, there is a strong tendency to transudation of the watery portions of the blood, resulting in dropsies in different parts of the body. The *corpuscles* are the *vital elements* of the blood, and they endow certain other elements, such as fibrin and albumen, with vital properties.

The *coagulation of the blood* consists in a new arrangement of its constituents, which occurs when the blood is removed from the vessels, or when the body itself dies. It

depends upon the spontaneous coagulability of the fibrin, (or its constituent elements), during which it forms a net-work of fibres, in the meshes of which are included the corpuscles, in groups, like small piles of money. These are somewhat more numerous near the bottom of the clot. This crassamentum, or clot, then contracts, and squeezes out the serum, which contains the water, albumen and salts. The corpuscles exercise a certain influence in the coagulation of the blood, but their immediate presence is not absolutely necessary to its performance. This may be shown by filtering frog's blood, diluted with thin syrup, on a fine paper filter, by which the corpuscles are kept back, and the liquor sanguinis which passes through, will afterwards coagulate. This is due to the vitality which it carries with it from the blood corpuscles.

When coagulation is observed under the microscope, there are first seen minute granules which aggregate to form star-shaped spots; these send out arms or projections

Fig. 64.



Clot of fibrin containing blood corpuscles entangled in its meshes.

in different directions, which are formed by the addition of granules in a linear manner. In this way the whole mass is converted into a fibrous net-work, enclosing the corpuscles in its meshes (Fig. 64).

The period required for coagulation varies much. It commences about two minutes after the blood is drawn, and

is completed in from half an hour to two hours afterwards; but continues to contract for many hours. The degree of regularity, and the completeness of the coagulation, depends on the previous elaboration of the fibrin, and the character of the surface on which it takes place, whether dead or living, warm or cold, moist or dry, etc. It is not generally supposed to become organized. When it coagulates in the open mouths of vessels, as in the arrest of hemorrhage from wounded arteries, the coagulum is absorbed and carried away, after the vessels have been closed, by the effusion and organization of lymph.

Fibrin does not exist as such in the blood, but is supposed to be formed in the process of coagulation, by the union of two previously existing albuminous substances, *fibrinoplastin* (or *paraglobulin*), and *fibrinogen*, united under the influenee of a "ferment" formed in the blood after its removal from the body. This is the theory of Schmidt. As the basis of this theory it has been observed that if blood-serum, or the fluid of hydrocele, or any serous effusion, be added to any other similarly constituted fluid, as the fluid of ascites, or from the pleural cavity, coagulation takes place, resulting in the production of fibrin. Another theory is that of Denis, according to which a substance exists in the blood, termed *plasmine*, in the proportion of 25 parts per thousand, which separates into two substances when removed from the body. One of these is *fibrin*, which coagulates, and the other is *metalbumen*, which remains in solution. Plasmine however, is regarded by some as a mixture of fibrinoplastin and fibrinogen.

Cupped and Buffed Condition of the Blood.—This condition of the blood generally occurs in inflammation, but is not exclusively confined to it, for it has been found to occur in anemia and in the blood of pregnant women during the last three months of gestation. It is occasioned by the increased tendency of the red corpuscles in these cases to run together and sink to the bottom of the vessel, and

thus leave the fibrin in the upper part. The fibrin then contracts very firmly—a circumstance which is favored by the comparative absence of the corpuscles—and in consequence of this contraction taking place, first on the surface and sides of the clot, and thence extending internally, it causes it to assume a concave, or cupped appearance, both on the surface and sides. The "*buffed*" appearance is due to the predominance of the fibrin in the upper part of the clot, the characteristic color of which is light yellow or *buff*. The clot also contains some white corpuscles in its meshes, and these are said to be increased in inflammation. The formation of the *cupped* and *buffed* coat, though favored by slow coagulation, is often observed in cases where the coagulation is more rapid than usual.

This condition of the blood is due, either to an absolute increase of fibrin, the corpuscles remaining the same; or to a diminution of the corpuscles, the quantity of fibrin remaining the same as in health. It has also been observed that, although the clot is firmer in inflammation, each single fibre is weaker and more easily broken down than that of a healthy clot. This is supposed to be due to the comparative absence of the corpuscles, from their having sunk to the bottom of the vessel during the process of coagulation

CIRCUMSTANCES WHICH PROMOTE COAGULATION. — *The natural temperature of the body*, from which the blood is taken (in man 98° to 100°F.) is most favorable to coagulation. *Rest* favors coagulation, but is not the cause, as some have supposed; for, although at rest, if *air be excluded*, as when it is within the living vessels, or covered with oil, coagulation is retarded for a considerable time. *Exposure to air* accelerates the process of coagulation; it takes place more readily in shallow vessels than in deep narrow ones. Also, the *multiplicity of points*; as in a lacerated, ragged wound, coagula are more readily formed than in clean, incised wounds. The addition of *less than twice* its bulk of *water* will promote the coagulation of the blood.

A low state of vitality of the vessels, from whatever cause, favors the formation of clots, or embolia, as they are called. These are, no doubt, frequently formed during life, as grooves, marked out by the current of blood, may be observed in clots found in the heart after death.

The contact of foreign matter promotes coagulation, even in the living vessels. Simon carried a single thread, by means of a fine needle, through a contiguous artery and vein, and allowed it to remain from twelve to twenty-four hours. A coagulum was formed in both artery and vein, that in the artery being pyramidal in shape, the base directed towards the heart, while that in the vein was larger and more irregular, the clot being chiefly collected on that side of the thread most remote from the heart.

The contact of dead animal matter accelerates coagulation in a remarkable degree, either within or without the living vessels. The presence of pus will produce coagulation in healthy blood, in from two to five minutes, and when injected into the veins it produces instantaneous death. When an artery gives way in the interior of an abscess, the hemorrhage is restrained, to a certain extent, by the presence of the pus which surrounds it.

Circumstances Which Retard Coagulation.—In some instances it would appear that the blood does not coagulate after death; for example, it was stated by Hunter, that in animals hunted to death, killed by lightning, electric shocks, or blows on the epigastrium, the blood did not coagulate; but it is probable that, even in these cases, it is only retarded, and ultimately coagulates, though imperfectly. It is further stated, by Polli, that the blood invariably coagulates before putrefaction sets in. Nevertheless, in cases of poisoning by hydrocyanic acid, and in death from asphyxia, coagulation may not take place, in consequence of the complete paralysis of the corpuscles and fibrin. In *inflammatory conditions* the blood drawn is usually slow in coagulating, in consequence of the sinking of the cor-

puscles; but the clot is preternaturally firm, especially at the upper part, where the buffy coat contracts, and produces the "cupped condition," which generally indicates a high state of inflammation. The coagulation of the blood is retarded, or altogether destroyed, by keeping it at a *temperature of* 120°F., while the natural heat of the body (98° F.) promotes it. It is also retarded by *cold*, but is not destroyed, even by freezing; for, if frozen as soon as it is drawn from the vessels, it will coagulate on being thawed.

The addition of *more than twice* its bulk of *water* retards the coagulation of the blood. *Continued agitation* also retards the coagulation for a time; but it ultimately takes place in the form of shreds, or strings. Blood while still *contained in the living vessels*, or effused in the *living tissues*, may continue in a fluid condition for a long period. Gulliver states that the blood included between two ligatures in a living vessel remained fluid three, four, or five hours. He also mentions one remarkable case, in which blood effused in the tissue of the loin, was found fluid when let out twenty eight days afterwards. In all these cases it coagulated in from fifteen to thirty minutes when withdrawn from the living parts. *Exclusion from the air* retards coagulation, as may be seen by covering the blood with a stratum of oil so as to exclude the air. The addition of *alkaline* or *earthy salts*, added to fresh blood, have a tendency to retard, and sometimes to prevent coagulation; and the same effect is produced by many vegetable substances, especially those of the narcotic and sedative class, as opium, hyoscyamus, belladonna, aconite, digitalis, etc. Gulliver mentions that he has kept horses' blood in a fluid state for fifty-seven weeks, with solution of potassium nitrate, and that it still coagulated, when diluted with water. The *presence of bile* retards the coagulation of the blood; and *septic* or *animal poisons* as the virus of serpents may retard or entirely destroy its coagulating power. It is also retarded by *imperfect aëration* of the blood during life, as in asphyxia.

FUNCTION OF THE CONSTITUENTS OF THE BLOOD.

FUNCTION OF FIBRIN.—It was formerly supposed that fibrin was that element of the blood which was directly drawn upon in the process of nutrition. This opinion was based on the then current theory that fibrin and muscle were identical in chemical composition; but it has since been shown, by Liebeg, that, so far from this being the case, the evidence is precisely the other way. There is no evidence whatever that fibrin (or its constituent elements) is used in the formation of any of the tissues, while, on the other hand, there are negative evidences that their formation and growth do not depend upon its presence. *Firstly*, the general purposes of nutrition may be served by a fluid which does not possess the property of coagulating spontaneously. *Secondly*, the small amount of fibrin found in the chyle is simply the result of elaboration in the lymphatics. *Thirdly*, the vegetable cell, which is essentially the same as the animal cell, is formed from an albuminous fluid, there being no fibrin in the juices of the plant. As a component of the blood, fibrin is of importance in giving it its proper degree of plasticity, and in this way facilitating its flow along the vessels. It also prevents the blood from exuding through the coats of the vessels, and arrests hemorrhage by plugging up the mouths of the open vessels. The want of the coagulating power of the blood is strikingly seen in cases of purpura hemorrhagica, in which the blood is not able to form a clot sufficient to close the mouth of the smallest vessel, or to form a barrier to surround abscesses, and prevent the infiltration of pus in the tissues. The same thing may be seen in the hemorrhagic diathesis, in which there is almost an entire absence of coagulable material. Fibrin was formerly supposed to be the material thrown out in the healing of wounds, and in the formation of adhesive bands in inflammation.

Some physiologists and pathologists, among whom are Zimmerman, Simon, Jones and Sieveking, etc., have ad-

vanced the idea that fibrin should be regarded as among those substances which have arisen from the decay of the blood, or the effete matter thrown into it from the tissues. In support of this view they advance the following arguments. *First*, that fibrin is increased in bleeding, starvation, anemia, and other states of exhaustion, while, at the same time, the red corpuscles are rapidly reduced by the same means. This view is also favored by the fact that in improvement of the breed of animals, the red corpuscles are increased, and the fibrin diminished. *Secondly*, there is only a small quantity of fibrin in fœtal blood, and in the renal veins; none in the egg, or the chyle until it enters the lacteals; and it is also smaller in quantity in the blood of the carnivora than in the herbivora.

FUNCTION OF THE RED CORPUSCLES.—One great function of the red corpuscles is to elaborate the materials of the blood which are to be used in the nutrition of the tissues, more especially those which supply the muscular and nerve tissues. They also assist in converting the albumen into fibrin, and in forming globuline and hemoglobine from the albumen and fibrin of the blood. They are also carriers of oxygen to the tissues, and deporters of carbonic acid from the tissues to the lungs, where it is eliminated. The former is due to the affinity of hemoglobine for oxygen. In anemia, when the corpuscles are very much diminished, the strength of the individual is correspondingly reduced.

The number of red corpuscles bears a close relation to the amount of respiratory power in the different classes of vertebrata: both of these are also found to be greatest in birds, less in mammals, and very low in most reptiles and fishes. The proportion of the corpuscles is greater among the carnivora than the herbivora. The want of red corpuscles in the invertebrata is compensated by the introduction of air through their tracheal apparatus, directly to the tissues themselves.

Function of the White Corpuscles.—These are, no doubt, also concerned in the elaboration of nutrient material for the tissues of the body, more especially in the invertebrate classes of animals. These corpuscles, which are oat-shaped in the larvæ of insects, are found more numerous just before each change of skin, at which time a larger supply of nourishment is required. After these changes have taken place, they are again diminished. The white corpuscles also contain a small quantity of iron, thus showing that the characteristic color of the red corpuscles is not due to this substance. In the vertebrata, on the other hand, the excess of colorless corpuscles is an evidence of unhealthy action; for example, they are very abundant in the blood of frogs that are young, sickly, or ill-fed. In the human subject, they are increased in the disease called leucocythæmia, in anemia, and also in inflammation according to some, although, in all probability, this only occurs in sickly, scrofulous, or tuberculous patients. When the circulation of the blood is examined in a bat's wing, or frog's foot, under the microscope, the white corpuscles may be observed running from the centre of the current to the circumference, and back again, and occasionally adhering to the sides of the vessels. They may also be occasionally seen passing through the coats of the vessels by virtue of their amœboid movements, or *diapedesis.* In this process they throw out arms or projections which enter the pores of the vessels and gradually force their way through. They thus pass out in large numbers in the healing process, and in inflammation, and are supposed to form the lymph. In this they are supplemented by the proliferation of connective tissue cells in the inflamed or wounded parts.

Function of Albumen.—This substance is the pabulum, from which the tissues of the body are formed. It is also used in the formation of the fibrin, globuline, and hemoglobine of the blood itself. Albumen by itself, however, is incapable of organization, and its conversion into the various

tissues must depend on their own power of appropriation. It also assists in holding in solution in the blood many of the metallic salts which exist in that fluid, or which enter the system. The albumen is derived from the food, and when any excess is taken into the system, it undergoes a retrograde change, and is eliminated by the liver and kidney. It is not excreted in health, but may be found in the urine in certain diseased conditions, as morbus Brightii, scarlatina, etc. Its presence in the urine may be detected by heat and nitric acid, which cause a precipitate in the form of flakes. It may also be found in the *vomita* and *dejecta* in cholera and yellow fever.

FATS.—The fatty matters taken into the system are intended in part, for the supply of the adipose and nerve tissue; but their chief use, however, is to afford material for that combustive process which is necessary for the maintenance of animal heat. It also contributes to the formation of milk. That which is stored up in the body may be looked upon as the surplus. Fat is often detected in the fæces, and such cases indicate a diseased condition of the liver or pancreas.

The other organic compounds which have been found in the blood, as sugar, lactic acid, urea, uric and hippuric acids, creatine, creatinine, fatty acids and odorous substances, but which do not properly form a part of it, are the result of a retrograde metamorphosis, either of the alimentary substances or of the tissues themselves, and are rapidly eliminated by the lungs, kidneys, liver, skin, etc.

The uses of the inorganic salts are not positively known; but such as have been investigated were referred to in the chapter on the proximate principles of the first class. The alkaline salts as sodium and potassium carbonates and phosphates are necessary to give the blood its alkalinity, to hold in solution the albumen, and to facilitate the passage of the blood through the capillaries, The salts are necessary also for the proper nutrition of the muscular tissue. Lime

phosphate, lime carbonate, calcium fluoride, etc., are required to build up the solid tissues, as bone, teeth, etc. The lime phosphate, in particular, may be regarded almost as a *histogenetic substance*, as it seems to be almost invariably present in newly-forming tissues, but more especially in the bone and teeth. Iron is an essential ingredient of the blood itself, entering into the formation of the hemoglobine. Water exists in large quantities, and is liable to considerable variation.

RELATION OF THE BLOOD TO THE LIVING ORGANISM.

The normal proportions of all the substances found in the blood are maintained partly by the selective power of the tissues in the process of nutrition and growth, and partly by means of the excretory apparatus, which removes the surplus materials. Each part of the body takes from the blood the peculiar substance which it requires for its nutrition, and thereby acts as an excretory organ, by removing that, which if allowed to remain in the blood, would act injuriously in the nutrition of the body generally; for example, the phosphates and carbonates which are deposited in the bones are as effectually removed from the blood as those which are thrown off by the urinary organs. Again, the rudimentary organs, as the hair in the fœtus, the mammæ in the male, etc., may be looked upon as excretions serving a useful purpose in the animal economy, by removing certain materials from the blood which might interfere with the proper nutrition of other parts of the body.

Although the blood may vary slightly in its composition and properties at different periods of life, yet we find that, taken as a whole, it presents such a constancy in its leading features, that we cannot fail to recognize in it some capacity for self-development, similar to that which the solid tissues possess. It retains its identity through life, just as a leg, an arm, or an eye. It has the power of maintaining itself from the new materials supplied to it from the food, and goes

through the successive phases of growth, maturity, and decay, similar to all vital organisms. The self-maintaining power of the blood is forcibly exhibited in the phenomena of disease, especially those of a febrile class, as the exanthemata, typhus, typhoid, etc. In all these cases the "morbid poison" would be eliminated by nature, if time were allowed to do so, the blood replenished, and the patient would resume his wonted health. In some instances, when a poisonous substance has entered the blood, the life may be saved by keeping up artificial respiration until nature has time to eliminate the poison from the system. In nearly all the toxic diseases of the zymotic class, there is a natural tendency to self-elimination of the poison, and of the products of its action on the blood either by the agency of the excretory organs, or by the local lesions which occur in these cases, and this occurs with such regularity that we are able to predict with certainty when the changes may be expected to take place. From the very nature of the action of these poisons on the blood, it is evident that no reliance whatever can be placed on the action of antidotes in checking their course. The object of treatment lies wholly in promoting the elimination of the morbid poison, in subduing local action, and supporting the vital powers of the patient during the continuance of the disease.

CHAPTER VIII.

CIRCULATION.

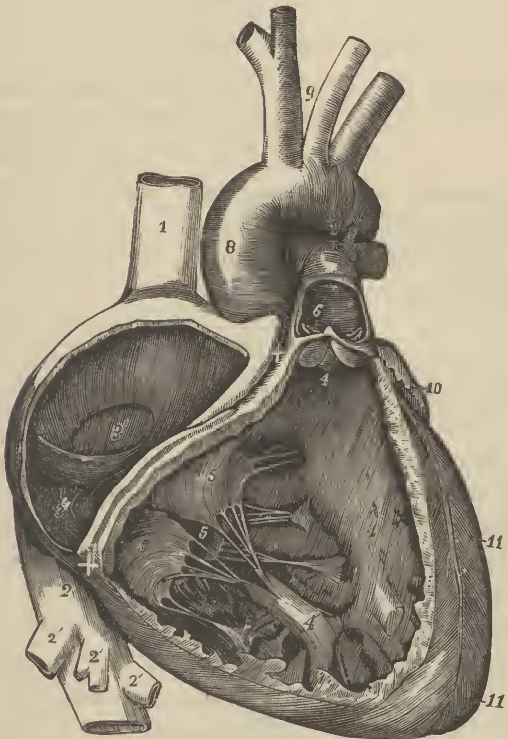
The object of the circulation of the blood is to carry to every part of the body the materials for its nutrition and growth, together with the supply of oxygen necessary for its vital actions; and also to carry away the effete substances which are formed as a result of the waste of the tissues. The organs concerned in this process are the *heart, arteries, veins,* and *capillaries.*

THE HEART.

The *heart* is the great central organ of circulation, situated in the middle mediastinum of the thorax, being placed obliquely, the base upwards and to the right side, on a level with the upper border of the third costal cartilage and corresponding to the interval between the fifth and eighth dorsal vertebræ, the apex corresponding to the interspace between the cartilages of the fifth and sixth ribs, one inch to the inner side, and two inches below the left nipple. It is a hollow, muscular organ, which, like a forcing pump, drives the blood through the vascular systen. It weighs from 9 to 10 ounces, and is about equal to the size of the closed fist of the individual, It varies in size and shape, in different classes of animals, from a simple, muscular tube, as in insects, to the complex double heart of man. In all animals, the organs of circulation are adapted and modified in structure to correspond with the organs of respiration. In the lower order of animals, as insects, the heart consists of a simple muscular tube, provided with certain valves at short distances apart. Corresponding to the situation of these valves, there are distinct constrictions in the tube, so

that it has the appearance of a series, or chain of hearts. As we ascend the scale, we first observe the subdivision of the heart into two cavities, the auricles and ventricles, in the acephalous mollusks. In fishes, also, the heart consists only

Fig. 65.



Right auricle and ventricle opened, to show their interior. 1, superior vena cava; 2, inferior vena cava; 2', hepatic veins; 3, right auricle; 3', fossa ovalis, below which is the Eustachian valve; 3'', coronary vein; +, +, auriculo-ventricular groove; 4, 4, cavity of the right ventricle, the upper figure is immediately below the semilunar valves; 4', large columna carnea or musculus papillaris; 5, 5', 5'', tricuspid valve; 6, in pulmonary artery; 7, aortic arch close to the ductus arteriosus; 8, ascending part or sinus of the arch covered at its commencement by the auricular appendix and pulmonary artery; 9, the innominate and left cartoid arteries; 10, appendix of the left auricle; 11, 11, the outside of the left ventricle, the lower figure near the apex.

of two cavities, the auricle, into which the blood is received from the veins, and a ventricle, which drives the blood into the main artery which supplies the gills. In reptiles, there are two auricles and one ventricle. One of the auricles

receives the blood from the lungs, the *pulmonic;* and the other, the blood from the veins of the body, the *systemic auricle.* They both open into a single ventricle, which propels the blood throughout the body, and also to the lungs.

In birds and mammals (including the human species) the heart consists of two auricles and two ventricles, separated by a complete septum, each auricle communicating with its corresponding ventricle, and each ventricle communicating with an arterial trunk. The course of the circulation is as follows:—The venous blood is returned from the body by the superior and inferior venæ cavæ, and poured into the right auricle; thence it passes into the right ventricle, being prevented from returning by the closure of the tricuspid valves; from the right ventricle it passes to the lungs, through the pulmonary artery, the opening being closed behind it by the coaptation of the pulmonary semilunar valves. The blood being aërated in the lungs, is returned to the left auricle through the pulmonary veins; this constitutes the *pulmonic* circulation. It next passes through the auriculo-ventricular opening into the left ventricle, being prevented from returning by the closure of the mitral valves; it is then propelled with con-

Fig. 66.

Diagram of the circulation.

siderable force into the aorta, the opening being closed behind it by the coaptation of the aortic semilunar valves, and is thence distributed to the various parts of the body, to be again returned by the veins to the right side of the heart. The latter constitutes the *systemic* circulation. On reference to the diagram there will also be seen a subordinate stream, or offset of the general or systemic circulation which passes through the liver; this is the *portal* circulation. The variation in the course of the blood during fœtal life is called *fœtal* circulation.

Proofs of the Circulation.—The circulation of the blood was discovered by Harvey in 1618. The main arguments by which he proved the circulation were as follows :— 1, The heart propels in half an hour, more blood than the whole mass in the body. 2, The blood spurts in a jetting manner from a wounded artery. 3, If true, the normal course of the circulation explains why the arteries were found empty after death. 4, If the veins were tied near the heart, it became pale and bloodless; if the artery were tied, the heart became distended. 5, If a ligature be drawn tightly around the limb, no blood can enter and it becomes pale and cold; if slightly relaxed, blood can enter but cannot leave the limb, hence it swells. 6, The existence of valves in the veins, which permit the blood to flow only towards the heart. 7, The constitutional disturbance resulting from poisons introduced at a single point.

To these may be added proofs accumulated since the time of Harvey, viz.: the effects of wounds of arteries and veins respectively; in the former hemorrhage may be arrested by pressure above; in the latter, by pressure below the seat of injury. The direct passage of blood corpuscles from small arteries, through the capillaries into the veins, seen by the microscope in the web of the frog's foot, the tail of the tadpole, etc. The injection of certain substances into the veins, which have been detected in the arteries a short time

afterwards. The valves of the heart are also so arranged as to permit the blood to pass only in one direction.

Muscular Structure of the Heart.—The heart consists of striated muscular fibres, and fibrous rings which serve for their attachment. The fibres are not arranged in bundles, but interlace with each other in an intricate manner, and adhere closely together, there being little or none of that areolar tissue which exists in the external muscles, and there is no appearance of sarcolemma. The fibres are also smaller than those of other parts of the body, and the striæ are less marked. The disposition of the fibres of the heart may be demonstrated by prolonged boiling, which hardens the fibres and facilitates their separation. The fibrous rings are *four* in number, the *right* and *left auriculo-ventricular*, the *aortic* and *pulmonary*. The former serve for the attachment of the muscular fibres of the auricles and ventricles, and also for the tricuspid and mitral valves; the latter for the attachment of the arterial vessels, semilunar valves, and muscular fibres of the ventricles. The walls of the left ventricle are 7 lines in thickness, those of the right about $2\frac{1}{2}$ lines; the walls of the left auricle are about $1\frac{1}{2}$ lines in thickness, the right 1 line.

Fig. 67.

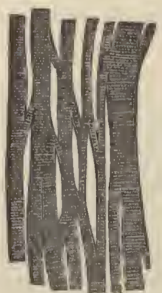


Fig. 68.

Fig. 67. Muscular fibres of the heart, showitg their striæ, divisions and junctions.

Fig. 68. Muscular fibres magnified, showing separate cells with their nuclei.

The Fibres of the Auricles.—These are divided into two sets or layers, a *superficial*, common to both, and a *deep* layer, proper to each. The *superficial* fibres run in a *transverse* direction across the bases of the auricles, and are most distinct on the anterior surface. The *deep* fibres consist of two sets, *looped* and *annular*. The *looped* fibres commence at the ariculo-ventricular rings in front, pass

upwards over the auricle, and return to the rings on the posterior part. The *annular* fibres surround the auricles in a circular manner, and are continuous with the circular fibres of the veins which open into them.

THE FIBRES OF THE VENTRICLES.—These consist according to Pettigrew, of *seven* layers, of which three are external, the fourth central, and three internal. In the *left* ventricle the fibres of the first or external layer, run almost vertically downwards, inclining somewhat from left to right, and are continuous at the apex with the seventh or internal layer, which pass upwards reversely from left to right; these two, are the only layers that are inserted into the auriculo-ventricular and aortic rings. Those of the second layer run more obliquely downwards from left to right, and are continuous at the apex with the sixth layer, which pass upwards with a corresponding obliquity in the reversed direction. The third layer is similar in course, but still more oblique in direction, and is continuous at the apex with the sixth layer. The fourth layer is horizontal or transverse (circular), and appears to be single. The internal layers are thicker than the external, so that the fourth layer is nearer the outer, than the inner surface of the ventricular wall. The fibres of the external layer curve around at the *apex* in a spiral manner, and form the *whorl* or vortex, constituting the entire thickness of the heart at this point. From the seventh layer are chiefly formed the musculi papillares and columnæ carneæ. The fibres of the first four layers pass across the septum from one ventricle to the other; this is specially noticeable at the back where there are some transverse fibres—the "hinge-like" fibres of the back of the heart. The *right* ventricle is similarly formed, except that the external fibres are continuous with the internal, not only at the apex, but all along the anterior coronary groove. The septum is formed of fibres from both ventricles, and the left half is twice the thickness of the right.

The heart is covered externally by a layer of *pericardium* and lined internally by a smooth shining membrane, the *endocardium*, which is continuous with the lining membrane of the arteries and veins. Both these membranes are covered with flattened epithelium (endothelium) which gives them a smooth and glistening appearance. The valves of the heart are formed by reduplications of the lining membrane, strengthened by connective and elastic fibres, and are attached by their bases to the tendinous rings. The *tricuspid* and *mitral valves* which guard the right and left auriculo-ventricular openings respectively, are also attached by their ventricular surfaces and borders to the *columnæ carneæ* by slender tendinous chords, the *chordæ tendineæ*, The *semilunar valves* which guard the orifices of the aorta and pulmonary artery, three in number for each, are placed side by side around the orifice, so as to form three little pouches, which lie flat when the blood is passing out, but immediately bulge out to prevent any return, the corpora Arantii closing in the space between the three segments in the centre.

Vessels and Nerves.—The heart is supplied by the anterior and posterior coronary arteries; the nerves are derived from the superficial and deep cardiac plexuses, which are formed partly by the cranial nerves, and partly by the sympathetic.

Action of the Heart.—The blood is propelled in its course by the alternate contraction and dilatation of the muscular walls of the auricles and ventricles of the heart. The two auricles contract together, and afterwards the two ventricles; and in each case the contraction is immediately followed by a relaxation. The contraction is called *systole;* the dilatation, *diastole.* The auricles gradually fill with blood flowing into them from the veins, part of which passes at once into the ventricles. When the auricles are distended, they contract and force the blood into the ventricles, completing their *diastole.* The latter immediately contract,

and their contraction, or *systole*, follows so rapidly, that it appears as if continuous with that of the auricles. The ventricles contract more slowly than the auricles, and empty themselves more completely than the latter, which always contain a small quantity of blood. The contraction of the ventricles upon the blood, closes firmly the auriculo-ventricular valves and forces open the semilunar, and the blood is forced into the aorta and pulmonary artery. The *musculi papillares* by their contraction, and attachment through the *chordæ tendineæ*, prevent the auriculo-ventricular valves from being everted into the auricles. The closure of the tricuspid valve is not always complete, especially if the ventricle is too full, and a small quantity of blood flows back into the right auricle. This has been called the *safety valve* action of this valve. The semilunar valves, as previously mentioned, lie flat to allow the blood to pass out but immediately fill, bulge out and meet, so as to prevent its return.

During contraction the heart appears to become longer and narrower, although, in reality, it becomes shorter and narrower. This may be demonstrated by placing the heart of a recently killed animal, as a frog or rabbit, on the table, and transfixing the base by means of a large needle, and inserting another at the apex, so as merely to touch it. If the organ is then stimulated to contraction by pricking it, the apex will be observed to recede from the needle, while the heart at the same time becomes narrower and shorter.

SOUNDS OF THE HEART.—The action of the heart is accompanied by sounds. These are two in number; the *first* or *systolic*, and the *second*, or *diastolic*. They follow each other in quick succession, and are succeeded by a pause, or period of silence, after which the first sound again recurs. The duration of the first sound is double that of the second, and equal to that of the pause. Thus, if the whole period be divided into *five* parts, the first two would

be occupied by the first sound, the third by the second sound, and the fourth and fifth by the pause, thus:

2 Parts occupied by the first sound..................	*Rhythm.*
1 Part occupied by the second sound...............	
2 Parts occupied by the pause........................	

A very short pause must also exist between the first and second sound, otherwise two distinct sounds could not be heard. This order of succession is called the *rhythm* of the heart, which, in a state of health, is remarkable for its regularity. The first sound of the heart is a heavy, prolonged sound, synchronous with the impulse of the heart, and is most distinctly heard over the apex; the second is a short, distinct sound, best heard over the base. These sounds somewhat resemble the sounds of the words "*come*" "*up*," whispered in rapid succession, the former representing the first sound, the latter, the second.

The *first* sound is in all probability, a compound sound, chiefly produced by the closure and vibration of the tricuspid and mitral valves, and the collision of the blood against the walls of the ventricles. It is also partly attributed to the muscular sound produced by the contraction of the ventricles, and the impulse of the heart against the walls of the chest.

The *second* sound is undoubtedly due to the closure and vibration of the aortic and pulmonary semilunar valves. They are forced back by the recoil of the blood, as one unfurls an umbrella—with an audible click as they tighten. This may be demonstrated by fastening one of the valves by means of a hook or ligature, to the side of the aortic and pulmonary arteries respectively, in some animal, as a calf, so as to allow regurgitation to take place, when it will be observed that a bellow's murmur takes the place of the second sound; but as soon as the valve is allowed to resume its play, the natural sound returns. It is thought by some that both sounds of the heart are produced by the same cause, viz: the tension of the valves. Disease of the valves

gives rise to murmurs which interfere with the distinctness of the sounds.

Impulse of the Heart.—The *impulse* of the heart is most distinctly felt in the space between the fifth and sixth ribs, two inches below and one inch to the inner side of the left nipple, and is sometimes called the *apex beat.* The force of the impulse varies in different individuals, and in the same individual at different times; it is very distinct in emaciated persons, and especially in hypertrophy of the heart. It is produced by the contraction of the spiral muscular fibres of the ventricles, which causes a tilting of the apex against the walls of the chest, and also by its change of shape in contraction, during which it becomes firm and globular, and impinges upon the walls of the chest. In its movement the apex describes a spiral curve from left to right, and from behind forwards. That the impulse of the heart is not due to the tendency of the arch of the aorta to straighten itself when distended with blood, and the elastic recoil of the parts about the base of the heart, is shown by the fact that the tilting movement of the heart will take place even when the apex has been cut off. The impulse of the heart corresponds with the pulse in the arteries, consequently the actions of the heart may be counted by the pulse at the wrist, or in any of the arteries. The beat is not a simple shock as it seems when felt by the finger, but may be shown by the *cardiograph* (a modified form of the sphygmograph) to be compounded of three or four shocks the strongest of which only, is felt by the finger.

Frequency and Force of the Heart's Action.—In a healthy adult, the pulsations vary from seventy to seventy-five per minute. The *frequency* of the heart's action diminishes from the commencement to the end of life, as will be seen from the following table, which represents the average number of beats in a minute:—

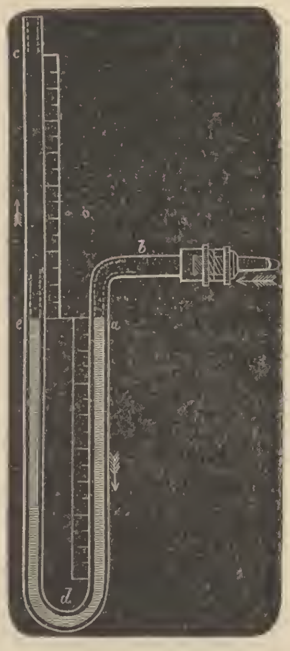
In the fœtus	150
At birth	130
In infancy	110
In youth	80
Adult age	75
Old age	65

Posture exercises a most remarkable influence on the frequency of the heart's action. It is most frequent in the erect posture, next to that, in the sitting, and least in the recumbent position. The pulse is also most frequent in the morning, becoming slower towards evening, and is very much diminished during the night. It is more frequent in those of a sanguine temperament, than in the phlegmatic, and in females than in males. Its action is accelerated after a meal, and still more so after bodily exertion, or mental excitement. In health, there is a nearly uniform relation between the frequency of the heart's action and the respirations, the proportion being about four of the former to one of the latter.

A certain rate of movement must be maintained in the circulation, and the impediment produced by friction must be overcome by the muscular force of the heart; and, since the left ventricle propels the blood through the whole system, while the right sends it only to the lungs, the walls of the former are twice as thick as the latter, and the force of the one is double the force of the other. The *force* of the heart's action may be estimated either by ascertaining the height of the column of blood which its action will support (Hales' method), or by causing the blood to act on a column of mercury (the method of Poiseuille and Volkmann.) Hales introduced a long pipe into the carotid artery of a horse, and found that the blood rose to the height of ten feet. From this and other experiments, on the lower animals, he concluded that the human heart would sustain a column of blood seven and a half feet high, the weight of which would be about 4½ lbs., on the square inch. Poiseuille's experiments were made with a glass tube, bent so as to form a horizontal

(*b*) and two perpendicular portions (*a. c.*), the latter being shaped like the letter U (Fig. 69), named the *hæmadynamometer.* The horizontal portion is adapted by a tube to the artery, and the perpendicular branches are partly filled with mercury, the rise and fall of which can be measured on scales placed behind them, and as the rise and fall are equal, the double of either will give the weight of the column which the force of the stream is able to maintain. The results corresponded closely with Hales' estimate, being about $4\frac{1}{4}$ lbs. Volkmann passed a solution of sodium carbonate into the horizontal branch, to prevent the blood from coagulating on the sides of the vessel. From his experiments, it appears that the force of the stream is capable of supporting a column of mercury about eight inches in height, or a column of blood about nine feet. But the force which the walls of the heart must exert in order to impart such a pressure to the blood which it propels, is equal to a weight of about 13 lbs. A modification of the hæmadynamometer for registering the variations of the force of the heart, or arterial tension is called a *kymograph* (Fig. 70). The open mercurial column supports a floating rod and pen (*a*), in contact with a revolving paper cylinder moved at an uniform rate by clock-work. The movements of the pen, caused by the up and down movements of the column of mercury, are inscribed or registered on the paper cylinder.

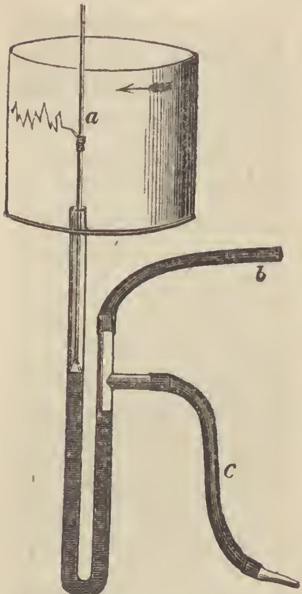
Fig. 69.



Influence of the Nerves on the Heart.—The heart's action is governed by two sets of nerves, the *excito-motor*

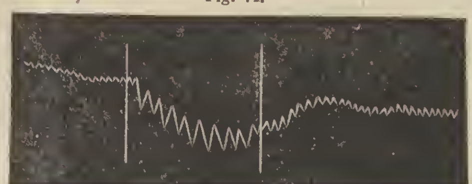
and *inhibitory*. The ganglia and communicating nerve fibres which preside over its action, are situated in the walls of the heart. They have been carefully studied in the frog, in which there are three collections of ganglia, *two* excito-motor—Remack's, near the inferior vena cava, and Bidder's, in the left auriculo-ventricular septum, and *one* inhibitory—Ludwig's in the interventricular septum. The heart receives its excito-motor influence through certain fibres of the sympathetic (inferior cervical ganglion and cardiac plexus) from the medulla oblongata, and its inhibitory or restraining influence from certain fibres of the pneumogastric (superior cardiac). Stimulation of the sympathetic nerves supplying the heart, by the galvanic current, increases the heart's action; while on the other hand, stimulation of the pneumogastric nerve or its inferior cut end diminishes it, and if the current is sufficiently trong, arrests it altoge ther, in diastole. Voluntary muscle so treated would induce tetanus, but the heart is completely relaxed; it knows no tetanus. The natural stimulus of the heart's action is the blood in its cavities, which excites *reflex*

Fig. 70.



Mercurial kymograph; (*a*) floating rod and pen; (*b*) tube connected with an alkaline solution; (*c*) tube and canula for insertion in an artery.

Fig. 71.



Before. During. After.

Tracing showing the effect of stimulation of the pneumogastric nerve.

action through the ganglia and nerves. The heart appears to be constantly acting, but it has also its constant pauses or intervals of rest, so that it differs from other muscles only in its shorter intervals of rest. The *effects of temperature* on the heart's action are interesting. In *cold blooded* animals the heart's action ceases at 25° F. and again at 104° F.; its frequency is increased from the lower until the maximum 72° F. is reached, and then it declines irregularly. In *warm-blooded* animals, as the rabbit, it ceases at 114° F. the frequency being increased from the lower to the maximum of 105° F.

ARTERIES.

The arteries are cylindrical tubes which convey the blood to the different parts of the body. They are found in nearly every part of the body, except the hair, nails, epidermis, cartilage, cornea, and the ultimate elements of the tissues. They were formerly supposed to contain air, because they were found empty after death, hence the name *arteries.*

STRUCTURE.—They consist of three coats, *external*, *middle* and *internal*. The *external coat* (tunica adventitia) is the thickest and consists of *areolar* and *elastic* tissue. In arteries of medium size, this coat is composed of two distinct layers, an inner or elastic, and an outer or areolar. In the large arteries both these coats are very thin, and in very small arteries the elastic coat is entirely absent.

Fig. 72.

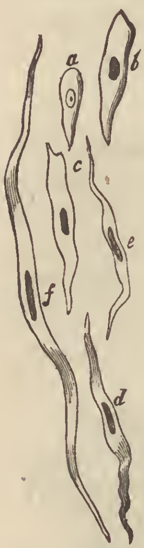
An artery in which the three coats are dissected.

The *middle coat* is thinner than the preceding, and consists of *muscular* (nonstriated) and *elastic* tissue, disposed chiefly in the transverse direction. In the largest arteries the muscular tissue forms only about one-third or one-fourth of the thickness of the middle coat, while in the

medium-sized arteries it predominates, and in the smaller it is purely muscular.

The *internal* is the thinnest, and consists of two layers, the inner or *epithelial*, (endothelial) and outer or *elastic*. The former consists of a single layer of tesselated epithelium, with round or oval nuclei; the latter is a delicate, transparent, fenestrated membrane, which in medium-sized arteries is strengthened by several laminæ of elastic tissue.

Fig. 73.



Nonstriated muscular fibre cells; (*a*) developing cell; (*b*) more advanced; (*d*, *e*, *f*,) fibre cells of human arteries.

The arteries are supplied with blood-vessels like the other organs of the body. They are called the "*vasa vasorum.*" They are derived from some of the smaller arterial branches, which ramify in the loose areolar tissue connecting the artery with its sheath, and are distributed to the external and middle coats, probably also to the internal. They are also supplied with plexuses of nerves, derived chiefly from the sympathetic system, but partly from the cerebro-spinal. It is through these that the calibre of the vessels is regulated.

FUNCTION OF ELASTIC TISSUE IN ARTERIES.—It protects them from the suddenly exerted pressure to which they are subjected at each contraction of the ventricle. Under this force, which might burst a brittle tube, their elastic walls dilate, and by thus yielding, break the shock of the force impelling the blood, and exhaust it before they are in danger of bursting from being over-stretched. Again, by their recoil, which occurs during the diastole of the heart, they exert a pressure which in some degree replaces the action of the heart. This pressure is equally diffused in every direction, and tends to drive the blood either onwards, or backwards to the heart; but the latter is prevented by the closure of the aortic valves; hence they *moderate the jetting movements* given to the

blood by the systole of the ventricles, and also *equalize the current* of blood by maintaining pressure upon the stream during the diastole. In this we cannot but admire the beautiful simplicity and harmony in the laws of nature. There is no loss of the force of the ventricles, for that part of their force which is expended in dilating the arteries is restored in full, according to the law of action of elastic bodies, by which they return to the state of rest with a force equal to that by which they were moved. The elasticity of the arteries also gives them a *capacity* for receiving, under certain circumstances, more than the average quantity of blood, and it enables them to adapt themselves to the various movements of the different parts of the body. In consequence of their elasticity, the arteries are not only dilated, but also elongated. This is most apparent in arteries which are curved.

FUNCTION OF MUSCULAR TISSUE IN ARTERIES. — When an artery is cut across, its divided ends contract, and the orifices may be partially or completely closed, owing to the contraction of the muscular tissue. This contraction is greater in the young than in the aged, and in animals than in man, and continues many hours after death. It is also increased by the application of cold, styptics, galvanism, irritation, or by torsion or twisting the cut ends of the artery. Owing to their contraction after death, the vessels cannot be injected until the rigor mortis passes off. The muscular tissue of the arteries can assist only in a very small degree, in propelling the onward current of the blood. The manner in which the arterial trunks taper towards their distal extremities, renders it mechanically impossible that the strong contraction of circular fibres would drive the blood onward; in fact, the tendency would be in the opposite direction. The principal use of the muscular tissue is to *regulate the supply* to different parts of the body, according to the activity of the function of each part at different times; for example, the brain does not require so much

blood during sleep as during mental labor; the stomach does not require so much blood during fasting, as during digestion, etc. The heart cannot regulate the supply to each part at particular periods; but it may be regulated by the contraction of the muscular coat of the arteries, or its passive dilatation, so as to *diminish or increase* the supply of blood according to the demand. The muscular tissue also assists the elastic in *adapting the vessels* to the quantity of blood they may contain, giving *uniformity to the amount of pressure* exercised on the blood, and maintaining the *tone* of the blood-vessels. Again, the contraction of the muscular coat of a wounded artery, first *limits*, and then *arrests the escape of the blood* when assisted by the formation of fibrin in the mouth of the wounded vessel. This is nature's mode of arresting hemorrhage (natural hemostasis). The contraction of the arteries is determined chiefly by the influence of the great sympathetic system.

FUNCTION OF THE ARTERIES. — From what has been already stated, we may infer that the function of the arteries is—*first*, to convey and distribute the blood to the different parts of the body; *second*, to equalize the current, and moderate the jetting movements given to the blood by the ventricles; *third*, to regulate the supply to the different parts of the organism according to the demand.

ANASTOMOSIS OF ARTERIES.—The arteries have a remarkable tendency to communicate with each other in their course, in order more fully to supply the organs to which they are distributed. This is called an *anastomosis*. One of the simplest modes is the union of two arteries to form one, as the union of the vertebrals to form the basilar. Another mode is, the union of two branches to form an arch from the convexity of which other branches are given off, which may in their turn form arches, and this may be repeated until the resulting branches are reduced to a very small size, when they terminate in the capillaries, as for example, the mesenteric arteries. A third mode, which is the

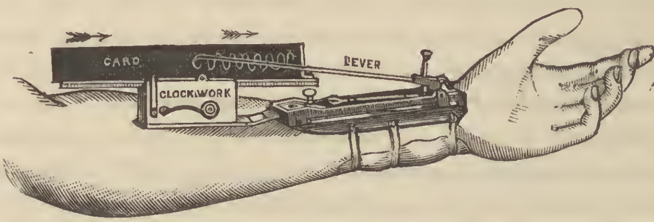
most remarkable, is the communication of two adjacent vessels by a distinct vessel passing from one to the other, as in the *circle of Willis*. Here the anterior cerebral arteries are united by a short cross branch—the anterior communicating, and the carotid on each side is united to the posterior cerebral by the posterior communicating. In this way the brain is protected in all its parts against loss of blood, if the circulation in any of the main channels should be arrested.

The most common form is found in the limbs, where the main trunk usually divides into two branches, from which smaller branches are given off, which communicate with each other at various points, especially around the joints. These branches also communicate with others from adjacent arteries, as for example, the deep femoral with the sciatic, etc. By such an arrangement, the proper nutrition of the limb is secured by collateral circulation in the event of the main trunk being ligatured, or otherwise occluded. In the application of a ligature, the surgeon should always make allowance for the anastomoses in the vicinity of the wound. In consequence of the free anastomoses between the adjacent branches, it is always necessary when a large artery is wounded, to apply a ligature both above and below the wound, in order to prevent the occurrence of subsequent hemorrhage.

Pulse.—When the finger is applied to the wrist, or any of the arteries of the body, it is felt to beat or pulsate in correspondence with the systole of the heart. The sensation communicated to the finger is due to the dilatation and elongation of the part, caused by the jetting movements of the current of blood in the vessel. Each jet of blood creates a wave, which moves along the whole arterial system. It is not supposed that the jet of blood from the ventricle imparts its pressure on the blood contained in the arteries so as to dilate the whole arterial system at once; but it displaces or propels the blood, and flows on by what may be called a *head-wave*. A certain time will be required for the

wave to travel from the heart to distant arteries, so that although the wave corresponds with the systole of the heart yet it is not in exact synchronism with it, the difference varying according to the distance from the heart. The longest interval is about one-sixth to one-eighth of a second. The rapidity of the wave is about $28\frac{1}{2}$ feet per second, or from 20 to 30 times as great as the velocity of the stream.

Fig. 74.



Sphygmograph applied to the Arm.

An instrument for delineating the character of the pulse is termed the *Sphygmograph.* It is made fast to the arm and the movements of a small button, which takes the place of the finger, are communicated by means of a lever, and registered by tracings in ink upon a card moved by clock-work (Fig. 74). In a healthy pulse the up-stroke or *percussion impulse* is nearly vertical, while the down-stroke is very oblique, and presents a slight notch or re-ascent; the more deficient in *tone* the pulse, the more distinct is the notch in the down stroke, and *vice versa.* In some instances, the re-ascent is so marked as to be perceptible to the finger, and is called a *dicrotic* pulse.

The *character of the pulse* will depend—First, upon the force of the heart; second, upon the integrity of its valves and orifices; third, upon the quantity and quality of the blood in the system; and fourth, upon the condition of the walls of the arteries, whether rigid or yielding, tense or flabby, etc. The qualities of softness or fulness, or wiryness, of compressibility or incompressibility, etc., which are familiar to the practical physician, are determined by the yielding or the resisting condition of the arterial walls.

Influence of the Nerves on the Arteries. — The arteries in all parts of the body receive nerve filaments from the sympathetic, called *vasomotor* branches. These give tone to the muscular fibres of the arteries, and if stimulated, as e.g., by an electric current, the arteries contract and diminish the supply of blood to the parts; if divided, the arteries are paralyzed and become dilated. The *vasomotor* nerves come primarily from the gray matter of the medulla oblongata, but communicate with the various ganglia of the sympathetic. The medulla is called the "vasomotor centre," and the ganglia of the sympathetic, "secondary centres." The reflex impressions received by these centres may either result in contraction or dilatation of the vessels. If the impression received through the sensory nerve of a part is sufficiently strong, it leads to contraction of all the blood-vessels of the body, except those in the part from which the impression was received which become dilated, The former action is called *excitomotor*, the latter *inhibitory*. The redness which follows the irritation of the skin is a good example.

VEINS.

The veins return the blood from the various tissues and organs, to the right side of the heart. They are more numerous, and, with the exception of the pulmonic veins, more capacious than the arteries. They commence in the capillaries, and uniting form trunks, some of which are superficial, and others deep, accompanying their corresponding arteries.

Structure.—In structure they consist of three coats, which resemble the arteries, except that the outer coat is thicker and contains some muscular tissue, and the middle coat is thinner. Muscular tissue is, however, entirely absent in the sinuses of the dura mater, uterus, and corpora cavernosa, cerebral veins, retinal veins, and the veins of the cancellous tissue of bones. Most veins have valves which pre-

vent the reflux of the blood. They are more numerous in the superficial than in the deep veins, and in those of the lower than the upper extremity. The valves are formed by reduplications of the lining membrane, semilunar in form, and are attached by their convex margins to the walls of the veins. They are generally arranged in pairs, occasionally there are three, but sometimes only one. In very small veins they are absent; also in the venæ cavæ, pulmonary veins, hepatic veins, portal vein, renal, uterine, ovarian, cerebral and spinal veins, veins of the cancelli of bones, and in the umbilical vein. The veins are supplied, like the arteries, by little vessels (vasa vasorum); but the nerves are not so easily detected upon them.

Circulation in the Veins.—In the veins, the blood moves in a continuous stream, and the velocity of the venous current is considerably less than the arterial. The circulation is produced by the *vis a tergo of the heart,* the *action of the capillaries*, the *contraction of the voluntary muscles,* and the *inspiratory movements of the thorax.*

The *vis a tergo* of the heart may produce, in certain conditions of the system, a distinct *venous pulse*, corresponding with the impulse of the heart, the wave having passed through the capillaries. This may be called the *communicated* or *systolic* venous pulse, and must be carefully distinguished from the *regurgitant* venous pulse, which is caused by the regurgitation which takes place, in some persons, into the venous trunks, during the systole of the right auricle. In health, the regurgitation is very small and indistinct; but when the right cavities of the heart are dilated, a large quantity of blood is regurgitated, and a distinct venous pulse is visible in the superficial and deep veins of the neck.

The *inspiratory movements of the thorax,* by enlarging the capacity of the chest, tend to create a vacuum, which is chiefly filled by the rush of air into the chest, but partly by the afflux of blood, which must be principally venous,

since the closure of the aortic valves would oppose any reflux in the aorta. This may be demonstrated by introducing a bent glass tube into the jugular vein of an animal, the vein being tied above the point where the tube is inserted, and the other end immersed in some colored fluid. It will be observed that at each inspiration the colored fluid will ascend in the tube, while during expiration it will either remain stationary or sink. Or it may be shown by the *hæmadynamometer.* The effect of inspiration on the veins is only observable in the larger ones. Forced expiratory movements on the other hand, retard venous circulation, as may be seen by holding the breath for a few seconds, or by straining, when the veins about the neck and face swell up and become distended, but immediately return to their former size when breathing is restored. In surgical operations in the region of the neck, the wounding of an enlarged vein which remains patulous, is liable to be followed by the entrance of air into the circulation during a deep inspiration, and sudden death is the result.

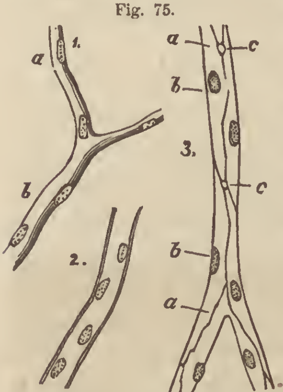
The *contraction of the voluntary muscles* has a most marked effect in favouring the circulation of the blood in the veins, as may be seen in cases of venesection, when the patient is directed to move his fingers freely. During muscular action a portion of the veins is compressed, and as the blood is prevented, by the valves in the veins, from passing backwards in the small vessels, it is necessarily forced onwards towards the heart. As the muscles are relaxed the veins again swell out, to be re-compressed by the renewal of the muscular force, and so on. This force is an important agent in maintaining the circulation, since the voluntary muscles are more or less active in nearly every position of the body, and the veins liable to be compressed by them.

The contraction of the *muscular tissue of the walls of the veins* also exerts considerable influence in the circulation of the blood in the veins.

CAPILLARIES.

The capillaries are the connecting link between the arteries and veins, and are found in all parts of the body except the uterine placenta, copora cavernosa of the penis, hair, nails, epidermis, etc. In structure they appear under the microscope, to consist of a homogeneous, finely fibrillated membrane, with cell nuclei which adhere to or are embedded in it, at certain distances apart. This is lined internally by a layer of transparent, elongated and flattened nucleated cells (endothelium). At the point of junction of some of the endothelial cells, small openings or *stomata* (Fig. 75, c) may be seen resembling those of serous membranes (p.101), through which the white corpuscles make an active exit, and the red ones are sometimes passively forced out. These appearances are readily seen after staining with solution of silver nitrate. The capillaries vary in diameter in the different tissues, the average being about $\frac{1}{3000}$ of an inch, (8.3 mmm) and their length is about $\frac{1}{30}$ of an inch (.8 mm). The smallest are those of the brain and mucous membrane of the intestines; the largest are those of the skin and medulla of bones. They form meshes, which vary in different tissues; for example, they are *rounded* in the lungs, *elongated* in the muscles and nerves, and *looped* in the papillæ of the tongue and skin. The closest network is found in the lungs, and choroid coat of the eye. In the lungs, the interspaces are smaller than the capillaries themselves. The network is also very fine in the iris, ciliary body, and liver. As a rule the more active the function of an organ,

Fig. 75.

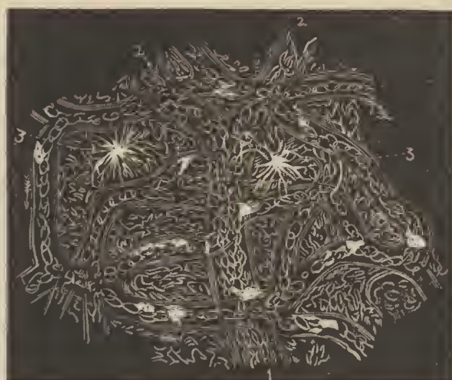


1. Capillary with a thin wall and nuclei a and b; 2, one with double contoured walls; 3, capillary vessel after the action of silver nitrate solution; a, endothelial cells; b, their nuclei; c, stomata.

the closer is the capillary network, and the larger its supply of blood. In the compound tissues the capillaries do not ramify among the ultimate particles of the tissues; thus in muscle the vessels lie between the fibres, but do not pierce the sarcolemma. In nerves, in the same way, they are separated from the nervous matter by the tubular membrane. In mucous and serous membranes they are imbedded in the sub-areolar tissue, which forms a nidus for them.

CIRCULATION IN THE CAPILLARIES. — The current of blood flows through the capillaries with a constant equable motion, as may be seen under the microscope in the frog's foot or bat's wing. In the central part of the current in the larger vessels may be seen the red corpuscles moving with considerable rapidity; while near the edges of the vessel there is a transparent stratum of clear plasma, in which may be seen some white corpuscles moving very slowly. The stream at the circumference is very sluggish, almost motionless, and is called the *still layer*. In the smaller vessels the corpuscles pass along in single file and sometimes become bent and otherwise distorted in order to acommodate themselves to the curvatures of the capillaries. Whenever the current is obstructed or retarded in any way, the white corpuscles accumulate in the affected part, and become more numerous in proportion to the red. The circulation of the blood in the capillaries is partly due to the *vis a tergo of*

Fig. 76.



Capillary plexus in the frog's foot, x 110; 1, trunk of vein; 2, its branches; 3, pigment cells. (*Wagner.*)

the heart, and *recoil of the arteries*, and partly also *to the attractive or selective power of the tissues*. The former has been already referred to, in connection with the heart and arteries. With regard to the latter, it is in the capillaries that those chemical and physical changes between the blood and the tissues take place, in which the phenomena of nutrition essentially consist. A certain force is generated by this interchange, which promotes the circulation of the blood through the capillaries. It is termed the *attractive or selective power* of the tissues, or by Carpenter *capillary power*. It may be explained as follows:—As the blood charged with oxygen and nutritious substances for the supply of the tissues approaches the capillaries, a rapid imbibition takes place with such energy, that it pushes before it into the veins, the blood from which the nutritious elements had been previously removed, and which also contains the effete matter. This force resembles that by which the circulation is maintained in plants, and in some of the lower order of animals.

The *capillaries are surrounded by a plexus of nerves*, similar to that of the larger vessels. Their contraction during anger and from fear, and their dilatation during blushing, can only be referred to the influence of the nerves, for in these cases the changes are so rapid that the heart has not time to effect them. Under one kind of nervous emotion the vessels contract, and empty themselves, and the countenance becomes deadly pale, as in anger, fear, etc. Under another kind of nervous emotion the vessels dilate, become filled with blood, and the cheek is suffused, as in blushing.

The heart's action alone is sufficient to carry on the circulation of the blood, but it is aided by other forces which are supplementary. The *combined forces* by which the blood is propelled throughout the body, are, *first* and *chiefly*, the muscular force of the heart; *second*, the recoil of the elastic walls of the arteries; *third*, the attractive or selective power of the tissues; *fourth*, the pressure of the

muscles among which some of the veins lie; *fifth,* the action of the muscular tissue in the coats of the veins; and *sixth,* the inspiratory movements of the chest.

VELOCITY OF THE CIRCULATION.

The velocity of the current of blood at any given point in the system, is inversely proportional to the sectional area at that point. The united area of the capillaries is 400 times as great as that of the aorta, and hence the velocity of the blood in the capillaries is about $\frac{1}{400}$ of that in the aorta.

Velocity in the Arteries.—The velocity of the circulation in the arteries, may be ascertained by an instrument similar to that used for measuring the force of the heart. It is greater than in any other part of the system. Volkmann estimates the velocity with which the blood moves in the carotid artery, at about *twelve inches per second.* It diminishes during the diastole of the ventricles and in arteries remote from the heart, as the metatarsal, in which it is 2.2 inches per second.

Velocity in the Veins.—The velocity of the venous current is to that of the arterial as two to three, or about *eight inches per second,* as nearly as can be ascertained.

Velocity in the Capillaries.—The rate of movement of the blood in the capillaries may be determined by the microscope. It is slower than in either the arteries or veins, being on an average, about $\frac{1}{30}$ *of an inch per second.*

Velocity in the Body.—It is estimated that the ventricles and auricles are each capable of holding about three ounces of blood, and that this quantity is propelled by either ventricle at each systole, and that the whole amount of blood in the system is about eighteen pounds. This would require ninety-six pulsations for its passage through either side of the heart, and allowing seventy-two pulsations to a minute, the time occupied in transmitting

the whole would be 1⅓ minutes. But it has been ascertained by experiments on animals, as the horse, that substances in solution, such as potassium ferrocyanide, barium nitrate, etc., may be detected in the blood drawn from the carotid artery within twenty seconds after it has been introduced into the jugular vein of the opposite side. In the dog, the heart's action may be arrested in eleven or twelve seconds, by the introduction of a solution of potassium nitrate in the jugular vein; in the rabbit in about four seconds, and in fowls in about six. The introduction of such poisons as hydrocyanic acid and strychnine, are equally rapid in their effects. Hence, it appears that the rapidity of the circulation is underrated in the estimate founded upon the capacity of the heart, and the number of pulsations in a minute. It has been estimated by Volkmann, that in man the whole circuit is completed in considerably less than one minute.

PECULIARITIES OF THE CIRCULATION.—These are observed in the *lungs, liver, brain, spleen* and *erectile organs*. The chief peculiarity in the pulmonic circulation is, that the artery carries venous blood to the lungs, and the veins return arterial. The portal circulation is peculiar in being a kind of offset from the general circulation. The peculiarity of the circulation in the brain is, that it is provided with a uniform supply of blood. This is secured by the number and tortuosity of the vessels, and their large anastomoses in the formation of the circle of Willis. The occurrence of large venous trunks or indistensible *sinuses* within the cranium, is also peculiar. It is also stated by Dr. Kellie, that in bleeding animals to death, the brain does not become exsanguine, owing to atmospheric pressure, unless an opening be made in the cranium. But this is disputed by Dr. Burrows, who concludes, from careful experiments, that the brain may become exsanguine without any apparent aperture in the cranium, and that, in health, slight variations may occur in the quantity of blood sent to the

brain. In the spleen, the most striking peculiarity is that each of the larger branches supplies chiefly that part of the organ to which it is distributed, having no anastomosis with the adjoining branches.

The *erectile tissues* are the *penis, clitoris, erectile tissues of the vagina,* and the *nipple* in both sexes. The venous plexuses of the erectile tissue become filled with blood, which swells and distends the organ, causing it to assume an erect condition. This influx of blood may be caused by local irritation, or by certain emotions of the mind communicated through the great sympathetic system. Erectile tissue consists of a plexus of veins with varicose enlargements enclosed in a fibrous envelope, with trabecular partitions. There are also some nonstriated muscular fibres, which are connected in some way with the process of erection. They may either by their contraction prevent the due return of blood from the parts, or by their relaxation allow the plexuses to fill with blood, and remain so until the stimulus to erection subsides, when they contract and gradually expel the excess of blood.

FŒTAL CIRCULATION.—In the fœtus, the course of the circulation is modified in consequence of the inaction of the lungs. The aëration of the blood is effected by the placenta, through which also the fœtus is nourished, so that the placenta serves the double purpose of a respiratory and nutritive organ, or in other words, it performs the office of the lungs and stomach in the fœtus. The course of the circulation in the fœtus is as follows:—The arterial blood is carried from the placenta to the fœtus, along the umbilical cord, by the umbilical vein. It then enters the umbilicus, and passes upwards along the free margin of the longitudinal ligament of the liver to its under surface, where it gives off two or three branches to the left lobe, and others to the lobus quadratus and Spigelii. At the transverse fissure it divides into two branches; the larger is joined by the portal vein and enters the right lobe; the smaller

passes onwards, under the name of the ductus venosus, which joins the left hepatic vein, where the latter empties into the inferior vena cava. Hence the blood reaches the vena cava in three different ways; most of it passes through the liver with the portal venous blood, and is returned to the vena cava by the hepatic veins; some passes through the liver directly, to be returned also by the hepatic veins; and the smallest quantity is carried on by the ductus venosus to the vena cava. In the inferior vena cava, the blood is joined by that which is being returned from the lower extremities and viscera of the abdomen; it then enters the right auricle, and guided by the Eustachian valve passes through the foramen ovale into the left auricle, where it is mixed with a small quantity returning from the lungs. From the left auricle it passes into the left ventricle, from the left ventricle into the aorta, to be distributed chiefly to the head and upper extremities—a small quantity passing into the descending aorta. From the head and upper extremities the blood is returned by the superior vena cava to the right auricle, where it is mixed with some from the inferior vena cava. It then passes into the right ventricle, and from the right ventricle into the pulmonary artery, but the lungs of the fœtus being almost impervious, only a small quantity is distributed to them by the pulmonary arteries, and is returned to the left auricle by the pulmonary veins; the greater part of the blood from the right ventricle passes through the ductus arteriosus into the descending aorta, where it is mixed with a small quantity of blood transmitted by the left ventricle into the aorta. It then descends along this vessel to supply the viscera of the abdomen, pelvis, and lower extremities—the greater portion, however, being conveyed by the umbilical arteries to the placenta.

When the child is born, and respiration established, an increased amount of blood is sent to the lungs, and the placental circulation is cut off. The foramen ovale gradu-

ally closes up, being completed about the tenth day. The ductus arteriosus contracts as soon as respiration is established, and is completely closed from the fourth to the tenth day. The umbilical arteries, between the umbilicus and the fundus of the bladder, become obliterated between the second and fifth days. The umbilical vein and ductus venosus also become obliterated between the second and fifth days. In some instances the foramen ovale does not close readily, and the blood continues to pass through into the left auricle after birth, giving rise to a bluish color of the surface of the body. This condition is called *cyanosis* or *morbus cœruleus*, and may be remedied by keeping the child on its *right side* for a few days.

There is also a peculiarity in the circulation of the blood in connection with the Malpighian bodies of the kidney, closely resembling the portal circulation, for which see structure of the kidney.

CHAPTER IX.

RESPIRATION.

As the blood circulates through the different parts of the body, it is deprived of a certain amount of its nutritive elements and oxygen, and becomes loaded with impurities, resulting from the wear and tear of the tissues ; hence it becomes necessary, not only that fresh supplies of nutriment and oxygen should be continually added to the blood, but also that provision should be made for the removal of the impurities. One of the most important and abundant of the impurities is carbonic acid, the removal of which, and the introduction of fresh quantities of oxygen, constitute the chief purpose of respiration.

THE LUNGS.

The organs of respiration are the *lungs.* They are two in number, situated one in each of the lateral cavities of the chest, separated from each other by the mediastinal space. They are provided with a single air tube, the *trachea,* which is divided into two branches, the right and left bronchus, one for each lung. Each bronchus, on entering the hilum of the lung, divides and sub-divides dichotomously throughout the entire organ until the branches terminate in the lobular bronchial tubes. Each lung is surrounded by a serous membrane—the *pleura.* That portion which covers the lung is called the *visceral layer,* and is connected to the lung tissue by the sub-serous areolar tissue ; it is then reflected around the inner surface of the chest forming the *parietal layer.* These two layers are smooth, moist and covered with epithelium ; they are everywhere in contact,

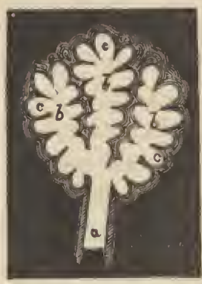
and glide readily upon each other. It is only when filled with air or fluid that there may be said to be a cavity between them.

The respiratory apparatus consists essentially of a thin, moist membrane, with blood-vessels on one side, and air or aërating fluid on the other, through which osmosis takes place. The lungs of the newt consist of cylindrical sacs running the entire length of the body, into which the air is forced by a sort of swallowing movement, and is afterwards regurgitated to make room for a fresh supply. In the frog and turtle, the cavity is divided into smaller compartments by thin septa, all of which communicate with the central cavity. The same principle or plan of construction obtains in the higher animals, the walls of the cavity being folded and refolded in order to increase the extent of aërating surface. In fishes and most aquatic animals the respiratory organs are in the form of *gills* or *branchiæ*, which are foldings of mucous membrane, containing blood-vessels. These are moved by muscles so as to bring them into contact with fresh portions of water, for the purpose of aëration. In certain of the lower order of animals unprovided with lung cavities, and in the vegetable kingdom, tracheal openings, or *stomata*, exist for the interchange of gases.

Minute Structure.—Each lung is divided into *lobes*, three for the right and two for the left, and each lobe is subdivided into *lobules*, which are held together by areolar tissue. They vary in size form $\frac{1}{12}$ to $\frac{1}{30}$ of an inch (2 to .8 mm) in diameter. They also vary in shape; those on the surface are large, of a pyramidal form, with their bases turned towards the surface; those in the interior are smaller, and of various forms. Each lobule is a miniature representation of the whole organ of which it forms a part, being composed of the terminal divisions of one of the smaller bronchial tubes and corresponding air cells, blood vessels, nerves and lymphatics, all held together by areolar tissue.

Each lobular bronchial tube, on entering the substance of the lobule, divides into from four to nine branches according to the size of the lobule, diminishing in size until they reach a diameter of $\frac{1}{50}$ to $\frac{1}{120}$ of an inch, (.5 to .2 mm). They are then continued onwards, their sides and extremities being closely covered by numerous saccular dilatations—the air cells—in consequence of which the tubes lose their identity, as cylindrical tubes, and present the character of irregular canals or passages—the so-called intercellular passages (Fig. 77).

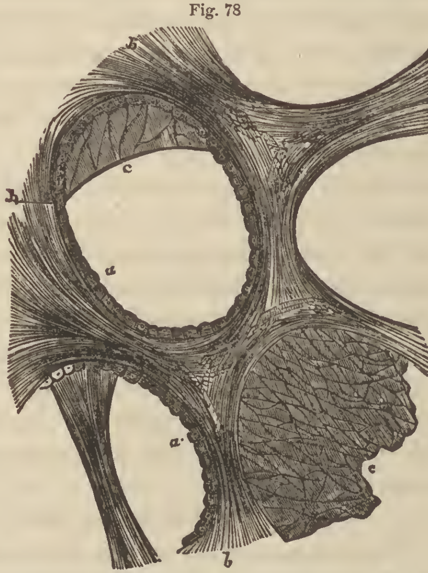
Fig. 77.



Lobule of the human lung; a, bronchial tube with its divisions; b, intercellular passages; c, air cells.

The *air cells* are small alveolar recesses, which vary from $\frac{1}{70}$ to $\frac{1}{200}$ of an inch, (.3 to .12 mm) in diameter, and are separated from each other by thin septa. They communicate with the terminal bronchial tubes which they surround by large circular openings; but do not communicate with each other except through the tubes. In these small bronchial tubes and air cells, the cartilaginous and muscular tissues are absent, and the mucous membrane is lined by squamous epithelium, while the trachea and bronchi are lined by

Fig. 78



Air cells of lungs, × 350; a, epithelium; b, fibres of elastic tissue; c, delicate lining membrane of air cells, with elastic fibres attached t it.—(*Kolliker.*)

columnar ciliated epithelium, among which are to be seen some cup or *goblet* cells (p. 99).

VESSELS AND NERVES.—The *pulmonary artery* conveys the venous blood to the lungs for aëration. It divides into branches which accompany the bronchial tubes, and terminates in a dense capillary plexus beneath the mucous membrane of the terminal bronchial tubes and air cells. Some of the capillaries also pass into the septa between the air cells so that both sides are at once exposed to the air. The blood, purified during its passage through the capillaries, is returned by the pulmonary veins to the left auricle of the heart. The *bronchial arteries* supply blood for the nutrition of the lung. They arise from the thoracic aorta, and divide into several branches, some of which accompany the bronchial tubes to which they are distributed, and terminate in the deep bronchial veins; others are distributed to the areolar tissue, and terminate partly in the superficial, and partly in the deep bronchial veins; whilst a few ramify upon the walls of the terminal bronchial tubes and air cells, and terminate in the pulmonary veins, the blood having been purified in its passage through the capillaries. The *bronchial veins*, superficial and deep, unite at the root of the lung, and empty on the right side into the vena azygos major, and on the left into the superior intercostal. The lungs are also abundantly supplied with lymphatics. They commence in irregular spaces or lacunæ in the walls of the air cells, or bronchi, and in the lymph spaces of the pleura pulmonalis.

Nerves.—The lungs are supplied by the anterior and posterior pulmonary plexuses of nerves formed chiefly by branches from the pneumogastric and sympathetic nerves.

MECHANISM OF RESPIRATION.

The movements by which fresh air is taken into the lungs, and by which it is again expelled, are those of *inspiration* and *expiration*. This is called the *mechanical*

act, in contradistinction to the *chemical* which relates to the changes which take place between the blood and the atmospheric air.

Inspiration.—During inspiration the chest is enlarged in every direction, but chiefly in the vertical. The latter is effected principally by the contraction of the diaphragm, and its consequent descent towards the abdomen. The increase in the lateral and antero-posterior diameters is due to the elevation of the ribs, both in front and at the sides. The *ordinary* muscles of inspiration are the diaphragm, external intercostals (and the internal in front), levatores costarum, serratus magnus, and serratus posticus superior. But in *extraordinary* or forced inspiration, as during a paroxysm of asthma, etc., the shoulders are fixed by the patient seizing something firmly, and the serratus magnus, pectoralis major and minor, trapezius, subclavian and scaleni muscles are called into action. The scaleni muscles fix the upper ribs, from which the external intercostals act, as from a fixed point, and elevate the lower ribs, by which the cavity of the chest is enlarged laterally and antero-posteriorly. This action is also promoted by the action of the other muscles previously mentioned.

Expiration.—Expiration succeeds inspiration, after a brief interval, and is accomplished, in ordinary respiration, by the *elastic recoil of the lungs* and walls of the chest, after they have been dilated, and partly by muscular action. The *ordinary* muscles of expiration are the abdominal muscles, internal intercostals except in front, serratus posticus inferior, and triangularis sterni. The *extraordinary* are the quadratus lumborum, latissimus dorsi, sacrolumbalis, and those which assist in fixing the spine and pelvis. In difficult breathing, almost every muscle in the body is made subservient to the action of respiration. The duration of inspiration is generally less than expiration, although in some instances they are nearly or quite equal, and there is a slight pause between the end of expiration and the com-

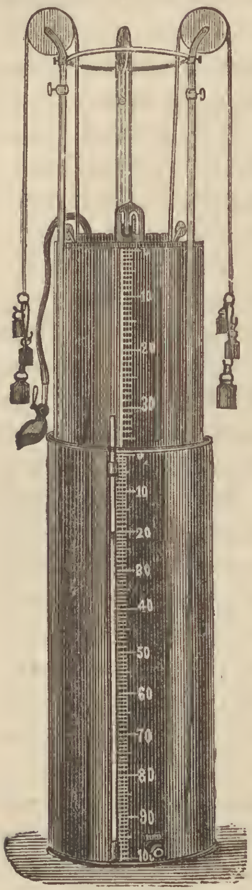
mencement of the next inspiration, and also between the acts. The succession of these acts constitutes the respiratory rhythm. During inspiration and expiration a sound is heard when the ear is applied to the chest, called the *respiratory murmur.* It is longer ($\frac{2}{3}$) and more distinct in inspiration, and is best heard in children, hence the term *puerile* respiration. The *rima glottidis* is also opened at each inspiration by the action of small muscles, and is closed somewhat at each expiration by the elastic recoil of the parts. The force of expiration exceeds that of inspiration by one-third.

FREQUENCY OF RESPIRATION AND RATIO TO THE PULSE. —The number of respirations in a healthy adult vary from sixteen to twenty in a minute. The proportion of respiratory movements to the pulsations of the heart is about one to four, and when this proportion is departed from there is reason to suspect some obstruction to the aëration of the blood, or some derangement of the nervous system. Any great disproportion between the number of respirations, and the number of pulsations or the amount of blood sent to the lungs to be aërated, is attended with dyspnœa. When the action of respiration is chiefly confined to the diaphragm and abdominal muscles, as in pleurisy, etc., the breathing is said to be *abdominal;* but when chiefly confined to the muscles of the thorax, as in peritonitis, etc., it is said to be *costal* or *thoracic.*

QUANTITY OF AIR RESPIRED.—The quantity of air taken in at each inspiration varies from twenty to thirty cubic inches; this is called *breathing* or *tidal air.* The quantity which an adult of average size (five feet eight inches), can inhale in a forced inspiration is about 230 cubic inches the excess being called *complemental air.* After ordinary expiration, such as that which expels the breathing or tidal air, a certain quantity remains in the lungs, which may be expelled by a forcible expiration; this is called *reserve or supplemental air.* A quantity still re-

mains, which cannot be forced out; this is called *residual air.*

Fig. 79.



Spirometer for measuring the quantity of air taken into the lungs.

The respiratory capacity of the chest is called the *vital capacity*, and it varies according to *stature, weight,* and *age*. The vital capacity of an adult, five feet eight inches in height, is about 230 cubic inches; and for every inch in height above this standard, the capacity is increased about eight cubic inches. The influence of weight is not so marked as that of height; but it tends to diminish the respiratory power, when beyond a certain limit. The vital capacity increases from fifteen to thirty-five years of age, and from thirty-five to sixty-five it decreases nearly one and a half cubic inches per year.

The total quantity of air which passes through the lungs in twenty-four hours varies from 300 to 400 cubic feet, depending on the state of the health, bodily exertion, etc. If the same air be rebreathed several times, it becomes loaded with carbonic acid and animal matter, causing headache, languor and depression, and if continued, serious results will follow sooner or later. Experience has shown that the minimum quantity of air which ought to be allowed for each person confined in prisons, hospitals, schools, etc., is about 1200 cubic feet. Provision should also be made for a constant supply of fresh air, and the removal of the impure, which is of even greater importance than the mere actual cubic space. The

ventilation should be such as will supply, at least from 1200 to 1500 cubic feet of fresh air for each person per hour.

INFLUENCE OF THE NERVES IN RESPIRATION.—The movements of respiration are presided over by the medulla oblongata, into which may be traced the principal excitor nerves, and from which proceed the principal motor nerves. The chief excitor of the movements of respiration is the pneumogastric nerve. When this is divided on both sides in the dog, the number of respirations are diminished about one-half, and irritation of its trunk is followed by an act of inspiration. The respiratory movements are caused by the presence of blood, loaded with carbonic acid, in the capillaries of the lungs, which makes an impression on the periphery of the pneumogastric nerve. The other excitors are the nerves distributed to the general surface of the body; but especially to the face. A current of cold air, or cold water dashed on the face, is sufficient to cause a deep inspiration; and a similar impression on the chest or body, or a slap on the buttocks, will excite inspiratory movements when they would not otherwise commence, as in the new-born infant, or in asphyxia. The first plunge into water, as in swimming, is usually accompanied by a deep inspiration. It is quite probable also, that the sympathetic nerves, which receive filaments from the spinal nerves and communicate with the pneumogastric, may be excitors of this function. The motor nerves concerned in the function of respiration are the phrenic, intercostals, facial and spinal accessory. The motor power of the respiratory nerves is exercised, however, not only in the muscles of respiration, but also on those which guard the entrance to the windpipe. Division or injury of the medulla oblongata is followed by sudden death from arrest of respiration. After division or injury of the spinal cord in the lower part of the cervical region, inspiration is performed by the diaphragm only, and when injured above the origin of the phrenic nerve, death occurs instantly, because of the inter-

ruption to all communication between the medulla oblongata and the diaphragm.

The respiratory movements, though partly voluntary, are in ordinary respiration essentially independent of the will, for example, during sleep, coma or anæsthesia, the respiratory function is carried on, although the person is entirely unconscious of the movements. At the same time, it is necessary that the respiratory actions should be partly under the direction of the will, since they are subservient to the production of those sounds by which individuals communicate their ideas to each other, as in speaking singing, etc.

MODIFICATIONS OF THE RESPIRATORY MOVEMENTS.—These are *coughing, sneezing, sighing, yawning, laughing, crying, sobbing* and *hiccup. Coughing* is caused by any source of irritation in the throat, larynx, trachea or bronchial tubes. This act consists, first, in a full inspiration, the glottis is then closed and a violent expiration takes place, by which a sudden blast of air is forced up the air passages by the diaphragm and abdominal muscles, forcing open the glottis and carrying before it any substance that may be present. In the act of coughing, the abdominal muscles act as forcibly on the abdominal viscera as on the lungs, and tend to the expulsion of their contents, but the voluntary contraction of the sphincters prevents any escape at the openings. The difference between *coughing* and *sneezing* is, that in the latter the blast of air is directed more or less completely through the nose, in order to remove any irritating substance there. *Sighing* is simply a deep inspiration, in which a larger quantity of air than usual is made to enter the lungs. *Yawning* is a still deeper inspiration, and is accompanied by opening the mouth widely, and contraction of the muscles about the jaws. In *laughing*, the muscles of expiration are in convulsive movement, and send out the air from the lungs in a series of jerks, the glottis being open. *Crying* is very nearly the same as

laughing, although occasioned by a different emotion. When the emotions are mixed, an expression is produced "*between a cry and a laugh.*" *Sobbing* is caused by a series of short convulsive contractions of the diaphragm, the glottis being closed. *Hiccup* is caused by a sudden convulsive contraction of the diaphragm, the glottis suddenly closing in the midst of it; the sound is produced by the impulse of the column of air against the glottis.

In speaking and singing, the vocal chords are made to vibrate as the air passes over them, and produce sounds which are moulded into words or notes by the tongue, teeth, lips, etc.

Changes in the Respired Air.—The air consists of a mixture of 20.81 parts oxygen to 79.19 of nitrogen, in 100 parts by volume, carbonic acid from .03 to .06 parts in a thousand, a variable amount of aqueous vapour, and a trace of ammonia. The *changes* produced on the atmospheric air by respiration are—1st, an increase in the temperature equal to that of the blood; 2nd, an increase in the quantity of carbonic acid and aqueous vapour; 3rd, a diminution in the quantity of oxygen. The nitrogen remains nearly the same, and a small quantity of organic matter is eliminated by the lungs. The air is heated by contact with the interior of the lungs to a temperature of about 98° F.

Exhalation of Carbonic Acid and Water.—The presence of an increased amount of carbonic acid in expired air, may be demonstrated by breathing through lime water, which becomes milky by the formation of insoluble calcium carbonate. It has been ascertained that there are about 4.35 parts of carbonic acid in 100 parts expired air, and subtracting the quantity in the air when inspired, leaves about 4.30 parts per cent. by volume, which is eliminated from the lungs at each ordinary expiration. This would amount to about sixteen cubic feet per day of carbonic acid, or nearly eight ounces of carbon. The elimination of

carbonic acid may be modified by a number of circumstances.

Digestion has been observed to be attended with an increased exhalation of carbonic acid, most distinct about an hour after eating; while *fasting*, on the other hand, diminishes it. *Alcohol, ether* and *chloroform* introduced into the system, are followed by a diminution in the quantity of carbonic acid exhaled. *Exercise* increases the exhalation of carbonic acid to about one-third more than it is during rest. During *sleep*, on the other hand, it is diminished, owing to the quietness of the breathing; but directly after waking, the amount is increased. *Age* and *sex* influence the quantity of carbonic acid exhaled; in males it increases from eight to thirty years of age, remains stationary from thirty to forty, and then diminishes to extreme age. In females, the quantity exhaled is always less than in males of the same age; it is increased from the eighth year to the age of puberty, and remains stationary as long as they continue to menstruate, but when menstruation ceases, from whatever cause, the exhalation of carbonic acid again augments, after which it diminishes to extreme age. *The temperature of the external air* has an important influence on the exhalation of carbonic acid. Observations made at various temperatures between 38° and 75° F. show that between these points every rise equal to 10° F. causes a diminution of about two cubic inches in the quantity of this gas exhaled per minute. *Cold*, on the other hand, within certain limits, increases it. *Moisture of the air* also favors the elimination of carbonic acid very materially. *The respiratory movements* influence the exhalation of this gas. When the respirations are increased in frequency, more carbonic acid is exhaled, although the percentage in proportion to the amount breathed is less. If the *air* have been *previously breathed*, the quantity of carbonic acid exhaled is very much diminished. It should also be borne in mind, that the continued respiration of an

atmosphere charged with the exhalations from the lungs and skin, is a most potent predisposing cause of disease, especially of the zymotic class.

The presence of an increased amount of *aqueous vapour* in expired air, may be shown by breathing upon a looking-glass, or polished metallic surface. The amount of aqueous vapour exhaled from the lungs in twenty-four hours may be estimated, in temperate climates, at from ten to twenty ounces. A certain amount of carbonic acid and water is also eliminated by the integument. *Ammonia* is an accidental constituent of expired air. The amount of *organic matter* given off from the lungs in twenty-four hours, is about three grains.

Amount of Oxygen Inhaled.—There is always less oxygen in expired air, than in the same quantity of air before respiration. Some of the oxygen unites with the carbon in the lungs to form carbonic acid; some is used in the chemico-vital changes which take place in the blood and tissues, and some is also used in oxidizing other substances besides the carbon, as for example, sulphur and phosphorus, which are eliminated in the urine in the form of sulphuric and phosphoric acid. Its absorption depends on the strong chemical affinity of hemoglobine for it. The quantity of oxygen absorbed is about 542 grains per hour, but it varies in different persons, and in the same person at different times. It is increased by food, especially of the farinaceous kind, and is diminished during fasting. The interchange of gases in the lungs does not accord with the law of "diffusion of gases," otherwise the proportion between the oxygen consumed and the carbonic acid exhaled should never vary. Besides, the law requires that both gases should be free, and under equal pressure; while, in reality, the gas in the blood is dissolved, under pressure, and is also separated by a membrane from that into which it is to be diffused.

The *nitrogen* of the atmosphere serves only to dilute the oxygen, and moderate its action in the system. Under ordinary circumstances there is very little difference between the quantity of nitrogen inspired and exhaled. The absorption of nitrogen is increased by fasting; while, under opposite circumstances, it is diminished. There is also a small quantity of nitrogen given off in the form of ammonia.

CHANGES IN THE BLOOD IN RESPIRATION.—1st, its color is changed ; 2nd, it absorbs oxygen ; 3rd, it exhales carbonic acid and aqueous vapour, small traces of ammonia and animal matter ; 4th, it contains more fibrin, and the temperature is increased from 1° to 2° F. The most obvious change is that of *color,* the dark venous blood being exchanged for the bright scarlet of arterial blood. The causes of this change have been already discussed in the chapter on blood. It is chiefly due to the absorption of oxygen, which is taken up principally by the hemoglobine of the corpuscles and partly by the plasma, and carried to the tissues ; and to the exhalation of carbonic acid which exists in the blood. The corpuscles also assume a biconcave shape, which reflects the light in such a way as to modify the color. Both oxygen and carbonic acid exist in the corpuscles and plasma of the blood, partly in a state of solution, and partly in a state of chemical combination ; but the corpuscles are the chief agents concerned in the absorption of the gases.

The *exhalation of carbonic acid* is favored by the moist condition of the membranes of the lung, which liquefies the gas. This fact may be demonstrated by filling a bladder with carbonic acid, and then placing it in water; it will soon be found to collapse and become completely emptied. Carbonic acid is being constantly generated in the blood, and is removed by exhalation from the lungs, as fast as it is produced; but if respiration is obstructed or seriously impeded, it accumulates in the blood, and may cause death

by its poisonous effects on the nervous system. Carbonic acid is formed in three different ways in the system: 1st, in the blood, by the action of oxygen on certain elements introduced in the food, as glucose and fats, giving rise to a certain amount of animal heat; 2nd, in the capillaries, by the union of oxygen with the carbon produced by the disintegration of the tissues; 3rd, in the lungs, by the decomposition of the alkaline carbonates.

EFFECTS OF THE ARREST OF RESPIRATION.—When respiration is interfered with by any obstruction, or from whatever cause, the circulation of blood through the lungs is retarded, and at length arrested. This prevents the exit of blood from the right ventricle, and is followed by venous congestion of the nervous centres, and all the other parts of the body. Besides, only a very small quantity of blood finds its way into the left side of the heart, and this is venous also. Hence, in death from asphyxia, the left side of the heart is nearly empty, while the lungs, right side of the heart and veins, are gorged with venous blood. The cause of the retention of blood in the lungs is due to the non-elimination of the carbonic acid; for blood loaded with this gas does not pass freely through the capillaries. The fatal result is due, to some extent, to the weakened action of the right side of the heart, in consequence of its over-distension; and also to the venous congestion in the medulla oblongata and nervous centres. The time which is necessary for life to be destroyed by asphyxia varies from one and one-half, to four minutes. In new-born and young animals, longer time is required than in older ones, because in the former the respiratory changes in the tissues are much less active. Animals will recover after simple deprivation of air for four minutes, but submersion in water for 1½ minutes destroys life completely. This is owing, in all probability, to the filling of the lungs with water. In drowning, very few persons recover who have been submerged more than three or four minutes. Cases have been

recorded in which recovery took place after the lapse of from fifteen minutes to half an hour; but in these instances it is probable that a state of syncope had come on at the moment of immersion.

CHAPTER X.

ANIMAL HEAT, LIGHT, AND ELECTRICITY.

HEAT.—This is closely connected with the process of respiration. The average temperature of the human body varies from 98° to 100° F.; birds from 106° to 111° F.; fishes and reptiles, about 51° F. In mammals and birds the temperature of the blood and internal organs is always very much above the external air, and they are therefore called "*warm-blooded animals.*" In fishes and reptiles, on the other hand, the temperature of their bodies differs but little from that of the medium which they inhabit, hence they are called "*cold-blooded animals.*" In both classes, however, there is an internal source of heat, but it is more active in the one than the other. Even in vegetables a certain amount of heat-producing power is occasionally manifest, as for example, in the flowering of plants, malting of barley, etc. In disease, the temperature of the body may deviate somewhat from the natural standard, as *e.g.*, in scarlatina, typhoid fever, etc., it rises as high as 106° or 107° F. In cholera, on the other hand, it often falls as low as 78° or 79° F. Continued high temperature in fever usually indicates a fatal issue, The highest temperature yet observed was reported by Dr. Teale, Eng. in a case of spinal injury, in which the temperature reached 122° F. The patient recovered. In some cases of yellow fever, a remarkable rise

takes place very soon after death, in one instance as high as 113° F., fifteen minutes after death. The temperature of the body in health, is about $1\frac{1}{2}$° F. lower during sleep than while awake. It is raised by exercise, and also after eating. The temperature of the new-born child is 1° F. higher than in the adult.

THEORY OF THE PRODUCTION OF ANIMAL HEAT.—There have been many theories regarding this subject. Lavoisier supposed that the oxygen taken into the lungs combined with the carbon of the blood and formed carbonic acid which was at once eliminated, the same amount of heat being produced as if the oxidation of a similar quantity of carbon in wood or coal had taken place, and that the heat thus developed radiated to the different parts of the body. This view was, however, soon ascertained to be incorrect, inasmuch as the heat of the lungs was found to be no greater than the rest of the body. It was also shown that the carbonic acid is formed principally in the blood and tissues, and that the oxygen is taken up by the blood corpuscles and carried away in the general circulation. According to Liebig, the heat of the animal body is produced by the oxidation or combustion of certain elements of the food, while circulating in the blood, as sugar, and fats. He therefore divided the food into two classes,—1st, *The plastic elements of nutrition,* which are used in the building up of the tissues, as albumen, fibrin, casein, muscular tissue, etc. 2nd, *The elements of respiration,* as starch, sugar, and fats, which are chiefly used in the production of animal heat, being oxidized in the circulation, and eliminated in the form of carbonic acid and water by the lungs. This theory, slightly modified, is the one which is most generally received.

The production of animal heat, then, is a phenomenon which results partly from the oxidation, or combustion, of certain elements of the food, and partly from the chemico-vital changes which take place in the blood, and the differ-

ent organs of the body. Every change in the condition of the organic constituents of the body, in which their elements enter into new combinations with oxygen, must be a source of the developement of heat; and the amount of oxygen consumed bears a certain relation to the amount of heat produced, the same amount of heat being produced, whether the union be rapid or slow. It is also found that the quantity of heat generated in the body is, "*cæteris paribus*," in direct proportion to the activity of the respiratory process. For example, in birds, whose function of respiration is very active, the animal temperature is very high (111° F.), while in mammals, whose respiration is less active it is less (98° to 102° F.) In fishes and reptiles, both the respiration and the animal heat are much lower than in either of the preceding (51° F.). Besides, the quantity and quality of the food used are different in different climates and seasons, for example, larger quantities of fats and oils are used in the food in cold than in warm climates, in order to supply material for the maintenance of animal heat. Even in temperate climates, more fats are used in winter than in summer.

INFLUENCE OF THE NERVOUS SYSTEM IN THE PRODUCTION OF ANIMAL HEAT.—It has been observed that after the division of the nerves of a limb the temperature falls, and this diminution of heat is still more decidedly marked in cases of paralysis; *e.g.*, the hand of a paralyzed arm was found to be 70° F., while that of the sound side had a temperature of 92° F. Again, when death is caused by a severe injury, or removal of the nervous centres, or in poisoning by woorara, etc., the temperature of the body rapidly falls, even though artificial respiration be kept up. On the other hand, severe injuries of the nervous system are sometimes followed by the direct opposite effect. This is supposed to be due to the dilatation of the arteries, in consequence of which the blood reaches the part supplied by those nerves in larger quantities; the nutrition is therefore more active.

Certain emotions of the mind may cause a momentary increase of temperature, while others cause a diminution. These circumstances, however, do not prove that heat is produced by mere nervous action independent of any chemical change. All the functions of the organism, as nutrition, secretion, excretion, etc., are under the influence of the nerves, and when they are divided, or otherwise injured, or paralyzed, chemico-vital action is in great measure suspended.

REGULATION OF THE TEMPERATURE OF THE BODY. — The temperature of the body is rendered uniform partly by loss of heat by radiation, and conduction; but chiefly by the evaporation which is continually taking place on its surface and to a small extent in the air passages. The introduction of food and drink at a lower temperature than the body, and the removal of the excreta, also abstract a small amount of heat. Evaporation of the perspiration produces cold, on the principle that "when a fluid passes into a state of vapour heat becomes latent," and hence the loss of heat will depend upon the amount of evaporation. When the atmosphere contains much moisture the evaporation is partly suspended, and all the effects of excessive heat are made more apparent than in a dry atmosphere, in which a greater amount of evaporation takes place, and consequently a greater amount of heat is removed from the system. Persons have been known to remain for several minutes in a dry atmosphere, heated to 250°F, without injury, the evaporation being sufficient to keep the temperature of the body within certain limits. Such a degree of heat in a moist atmosphere would be certain to cause serious injury.

In fevers and inflammation, the skin is hotter than in health, and is also dry; this is owing to the arrest of the natural secretion or perspiration, in consequence of which there is little or no evaporation to produce cold. In such cases great benefit will be derived from sponging the body frequently with cold or tepid water.

LIGHT

The evolution of light from the living human body, is a phenomenon of rare occurrence. Luminous exhalations have been frequently observed in burial grounds, and a luminous appearance has been sometimes noticed in newly dissected subjects in the dark. This is due to the development of phosphoretted hydrogen during decomposition of the tissues. A luminous appearance has been observed in old sores in the living subject, which were in a state of decomposition. It is also said that an evolution of light has been noticed, in two or three instances, in patients in the last stage of phthisis. The light in these cases, was observed to play around the face, and, in all probability proceeded from the breath, which had a peculiar smell, and was probably charged with phosphoretted hydrogen. The urine also, in some instances, has a luminous appearance, depending upon the presence of unoxidized phosphorus which it contains. The breath of an animal may be rendered distinctly luminous by injecting phosphorus dissolved in olive oil, in the proportion of two grains to the ounce, into the veins.

ELECTRICITY.

This is generated by *chemical union* or *decomposition*, *heat*, and *motion* or *friction*. There are no two parts of the body, except probably those of opposite sides, whose electrical condition is precisely the same. This depends on the difference in the functional activity of the parts; *e.g.*, the skin, and most of the internal membranes, are in opposite electrical states. *Electrical currents* exist in muscles and nerves; this may be demonstrated by means of the *galvanometer*. The direction of the current is constant in each muscle; but different muscles have different currents, *e.g.*, in the gastrocnemius of the frog, the direction is from the foot towards the body; while in the sartorius it is the reverse. But, taking all the muscles of the limb together, the differ-

ent currents are so unevenly balanced, that a constant current is established in one direction of the limb, and this, in the frog, is from the foot towards the body. The current of a man's arm is from the shoulder to the fingers.

When the two cut ends of a muscle are placed against the electrodes of a galvanometer, a very slight deflection of the needle is observed, and the same is the case with two points of a longitudinal section which are equally distant from the middle of the muscle. But the most powerful influence on the galvanometer is produced when to the surface of a muscle is applied one of the electrodes, and the cut end brought in contact with the other, These results may be obtained with small portions of muscle, even with a single fasciculus. Hence, it would appear, that each integral particle or sarcous element is a centre of electromotive action, and contains within it positive and negative elements, the arrangement of which represents a galvanic pile thus :

$$\begin{array}{|c|}+\\-\\+\\-\\+\\-\\+\\-\end{array}$$

It is supposed by some, that the light spots in the muscular fibrillæ are electro-positive, and the dark spots electro-negative. It has also been observed, that during contraction of the muscle the electric current is diminished. This may be exemplified by means of a common battery, It will be observed that when the poles are held tightly in the hands, and the muscles firmly contracted, the shock is not so readily transmitted as when they are held gently. Since electricity is transmitted both by the muscles and nerves, it is probable that contraction of the former alters slightly the relative position of some of the positive or negative elements, and in this way the power of conducting by the muscles is, to a certain extent destroyed.

There is also an electric current in nerves, similar to that in the muscles. When a small piece of nerve, recently obtained from the living body, is placed so that its surface rests on one of the electrodes, and its cut extremity touches the other, a considerable deflection of the needle is produced in

a direction which indicates that the current is from the interior to the exterior of the nerve. If the cut ends are applied to the two electrodes respectively, no marked effect is observed. The most powerful effect is produced by doubling the nerve in the middle, and applying both ends to one electrode and the loop to the other. The nervous current, like the muscular, is due to the electromotor action of the molecules of the nerve. The term *electrotonus* is applied to the condition of the nerve which exists during the time of electric stimulation. The irritability of the nerve is increased in the region of the negative pole or kathode, and is known as *katelectrotonus,* while it is diminished in the region of the positive pole or anode and is known as the condition of *anelectrotonus.* Electric currents are conveyed by nerves as well in one direction as another. The body would become surcharged with electricity were it not that the equilibrium is maintained by the free contact which is continually taking place between it and surrounding bodies. It is only when the body is insulated that it becomes apparent. The electricity of man is generally positive; of woman, more frequently negative ; and irritable men, of sanguine temperament, have more free electricity than phlegmatic persons. In some persons a crackling noise is produced when articles of dress, worn next the skin, are being removed, especially in dry weather. A case of a lady is mentioned in the *American Journal of Medical Sciences* (1838), in whom the generation of electricity was so great, that whenever she was insulated by a carpet, or any other feebly conducting medium, sparks passed between her body and any object she approached. As many as four sparks per minute would pass from her finger to the brass ball of the stove, at the distance of one and a half inches. This phenomenon was accompanied with a good deal of pain.

In some persons, a sufficient amount of electricity may be generated, when insulated by a carpet, to enable them to ignite a recently extinguished gas jet, by means of the sparks which pass from the fingers.

Some animals possess organs in which electricity may be generated and accumulated in large quantities, and from which it may be discharged at will. The most remarkable examples are to be found in certain fishes, the best known of which are the *torpedo*, or electric ray, and the *gymnotus*, or electric eel. The shock of the gymnotus is sufficiently powerful to kill small animals; that of the torpedo is not severe, but sufficient to benumb the hand that touches it.

Sparks of electricity may be produced in most animals having a soft fur, by rubbing the surface, especially in hot weather. This may be easily demonstrated by smoothing the back of a cat with the hand, in a darkened room, rubbing the horse in a dark stable, or by scraping sugar in the loaf in a dark pantry.

CHAPTER XI.

SECRETING GLANDS AND THEIR SECRETIONS.

THE LIVER.

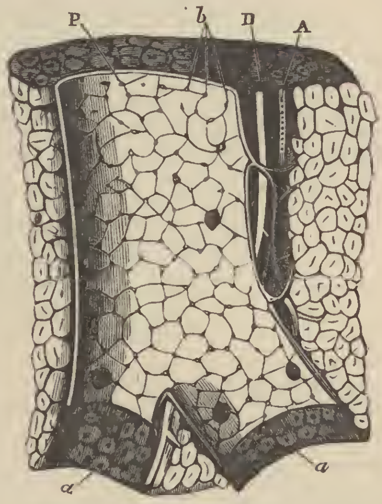
This is the largest gland in the body, situated in the right hypochondriac region, and extending across the epigastric into the left hypochondrium. It measures from ten to twelve inches from side to side, and from six to seven from before backwards, and weighs about three to four pounds. It consists of *five* lobes, which are mapped out on its under surface by *five* fissures. It is mainly divided into two lobes, the right and left, by a longitudinal fissure, the anterior portion of which is called the umbilical fissure, and the posterior part, the fissure for the ductus venosus. The right lobe is six times as large as the left, and presents on its under surface the lobus quadratus, lobus caudatus, and lobus Spigelii separated from each other by the transverse fissure, the fissure for the gall-bladder and the fissure for the vena cava. The transverse fissure is sometimes called the *hilum*, and is situated, as in the lungs, kidneys, spleen, etc., nearer the posterior than the anterior border. The liver is intended mainly for the secretion of bile, and is also supposed to effect important changes in certain constituents of the blood in its passage through the gland.

Minute Structure.—The liver is surrounded by a reflection of the peritoneum, which constitutes its serous covering. This is attached to the substance of the gland, except at its point of attachment to the diaphragm and in the

bottom of the different fissures, by fine areolar tissue. The substance of the liver consists of lobules held together by delicate areolar tissue, the ramifications of the portal vein, hepatic artery and ducts, hepatic veins, nerves and lymphatics.

The lobules (acini) are small, oval or roundish bodies, about the size of a millet seed measuring from $\frac{1}{10}$ to $\frac{1}{20}$ of an inch (2.5 to 1.2 mm) in diameter. They surround the the small sublobular branches of the hepatic vein, to which each is connected at its base by a small intralobular branch. When divided longitudinally, they present a foliated margin, and on a transverse section, they have a polygonal outline. When one of the sublobular hepatic veins is laid open, the bases of the lobules may be seen through the thin walls of the vein on which they rest. The base of each lobule presents a polygonal outline, in the centre of which may be seen the orifice of the intralobular vein. This gives them the appearance of a layer of tesselated or pavement epithelium.

Fig. 80.

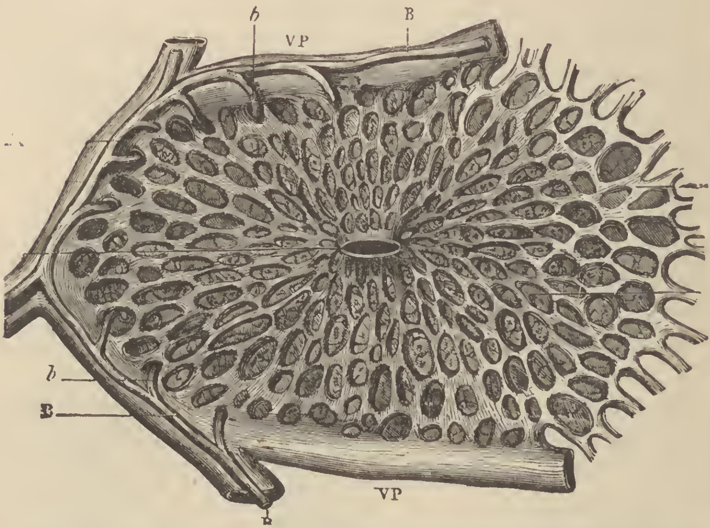


Longitudinal section of a portal canal containing (P) portal vein; (A) hepatic artery, and (D) hepatic duct. Lobules are to be seen to the right and left, and also shining through the thin wall of the vein; in the centre of each lobule is seen the intralobular vein; a, a, portion of the canal from which the vein has been removed; b, openings of the interlobular veins.

Structure of the Lobules.—Each lobule is a miniature representation of the whole gland of which it forms a part. It consists of a mass of cells, a plexus of biliary ducts, an intralobular vein (which is the commencement of the hepatic vein), arteries, nerves, and lymphatics.

The *hepatic cells* form the chief mass of the substance of a lobule; they lie in the interspaces of the capillary plexus, so as to form rows, which radiate from the centre to the cir-

Fig. 81.



Hepatic lobule. In the centre is seen the intralobular vein; VP, termination of the portal vein around the lobule, from which a capillary plexus proceeds towards the centre in the meshes of which are seen the hepatic cells; B, b, biliary ducts, arising within the lobule. (Claude Bernard.)

cumference of the lobule (Fig. 81). They are generally spheroidal in shape, but may be polygonal from mutual pressure, and vary in size, from $\frac{1}{1000}$ to $\frac{1}{2000}$ of an inch (25 to 12.5 mmm.) in diameter. Each cell contains a distinct nucleus, sometimes two, and in the interior of the nucleus a highly-refracting nucleolus, and some granular matter. The contents of the cell are viscid, and contain yellow particles of colouring matter, and some oil globules.

Fig. 82.

Hepatic Cells. (Frey.)

BILIARY DUCTS.—These commence within the lobule by a minute plexus of ducts (bile capillaries), with which the cells are in immediate contact. The ducts then form a

plexus between the lobules (interlobular), and the interlobular branches unite into vaginal branches, which lie in the portal canals. These branches finally join to form two large trunks, which leave the liver at the transverse fissure, and uniting form the hepatic duct.

Portal Vein.—The portal vein, on entering the transverse fissure of the liver, divides into two branches, one for each lobe, which are situated in the portal canals, together with the branches of the hepatic artery and duct, nerves and lymphatics. These vessels are surrounded by areolar tissue, continued inwards from the transverse fissure of the liver, called Glisson's capsule. The portal veins, in their course in these canals, give off vaginal branches, which form a plexus. From this plexus and from the portal vein itself, small branches are given off, which pass between the lobules and cover their external surface, called interlobular; these then pierce the lobules, and form a capillary plexus within each, from which arises the intralobular vein.

Hepatic Artery.—This takes precisely the same course as the portal vein and hepatic duct. It is intended chiefly for the nutrition of the liver. It gives off in the portal canals the vaginal branches, which supply the coats of the portal vein and hepatic ducts, and also interlobular branches, which pass between the lobules; the latter pierce the lobules, and terminate in the radicles of the intralobular vein. They are supposed by some to terminate in the radicles of the portal vein, but this is improbable.

Hepatic Veins.—The hepatic veins commence in the interior of the lobules in the intralobular veins, which arise in the centre of the lobules, and leave them at their bases to join the sublobular veins. The sublobular veins unite to form larger branches, and these join again to form the large hepatic veins, which terminate in the inferior vena cava.

For the secretion of the bile, and its function, see chapter on digestion.

THE KIDNEY AND ITS SECRETION.

The kidneys are intended for the secretion of urine. They are situated in the back part of the abdominal cavity, one in each lumbar and hypochondriac region, extending from the eleventh rib to within two inches of the crest of the ilium. The right is somewhat shorter and situated a little lower than the left. They are invested by a thin, smooth, fibrous capsule, which is very easily removed from the surface of the gland, and weigh from four to six ounces each.

STRUCTURE.—The kidney consists of two different substances, an *external or cortical*, and an *internal or medullary* substance. The *cortical substance* forms about three-fourths of the whole gland, is reddish in color, soft, granular, and friable in texture, and presents numerous reddish bodies (the Malpighian bodies) in every part of it, excepting towards the free surface. It is composed of the convoluted tubuli uriniferi, blood vessels, nerves and lymphatics, held together by a small quantity of areolar tissue. The cortical substance is from $\frac{1}{3}$ to $\frac{1}{2}$ an inch in thickness opposite the base of each pyramid, and is called the *cortical arch.* It also sends numerous prolongations inward towards the sinus, between the pyramids; these are called the *cortical columns* or *columns of Bertini.*

Fig. 83.

Longitudinal section of the kidney; the swellings upon the surface mark the original constitution of the organ, as made up of distinct lobules.—1. The supra-renal capsule. 2. The cortical portion of the kidney. 3, 3. Its medullary portion, consisting of cones. 4, 4. Two of the papillæ projecting into their corresponding calyces. 5, 5, 5. The three infundibula; the middle 5 is situated in the mouth of a calyx. 6. The pelvis. 7. The ureter.

The *Malpighian bodies* are found only in the cortical substance. They are small round bodies, of a deep red color, and of the average diameter of $\frac{1}{120}$ of an inch. They are capsular dilatations of the

commencing tubuli uriniferi, and are scattered irregularly in the columns of Bertini, but regularly arranged in double rows in the cortical arches. Within each body or capsule may be observed a vascular tuft or glomerulus, which consists of the ramifications of a small artery, the *afferent* vessel, which, after piercing the capsule, divides in a radiated manner into several branches, which ultimately terminate in a finer set of capillaries. The blood is returned from these by a vein, the *efferent* vessel, which pierces the caspule near the artery and forms a venous plexus with other efferent vessels around the adjacent tubuli (Fig 84). The capsules are lined by a layer of epithelium, which is believed by some to be prolonged over the tuft of vessels; while others are of the opinion that the tuft is wholly uncovered. The tuft in the frog, and other reptiles is covered by ciliated epithelium.

Fig. 84.

Plan of the renal circulation in man and Mammalia. a, Terminal branch of the artery, giving the afferent twig 1, to the Malpighian tuft m, from which emerges the efferent vessel, 2. Other efferent vessels, 2, are seen entering the plexus of capillaries, surrounding the uriniferous tube, t. From the plexus the returning vein, v, springs.

The *medullary substance,* which forms about one-fourth of the gland, is pale-red in color, dense in texture, and presents a striated appearance on account of the number of diverging tubuli uriniferi. It consists of *conical masses* the "Malpighian pyramids", which vary in number from eight to eighteen, their bases being directed towards the circumference of the organ, and their apices towards the sinus, in which they terminate by smooth rounded extremities, called the papillæ of the kidney. The conical masses consist of the tubuli uriniferi, blood-vessels, nerves and lymphatics, held together by areolar tissue.

The *tubuli uriniferi* commence at the apices of the cones by small openings; as they pass towards the base they divide

Fig. 85.

A. Portion of uriniferous tube magnified. B. Epithelial cells more highly magnified.

and sub-divide, and diverge until they reach the cortical sub stance, when they become convoluted and anastomose freely with each other and terminate in the Malpighian capsules. There are also some convoluted tubes in the Malpighian pyramids, the *looped tubes of Henle*, which descend to a certain distance in the medullary pyramid and return in loops to rejoin the convoluted tubes. The diameter of these looped tubes is about $\frac{1}{1200}$ of an inch (20 mmm). The number of orifices on a single papilla is about five hundred. The average diameter of the tubes is about $\frac{1}{500}$ of an inch (50 mmm) and they consist of a nearly homogeneous membrane lined with spheroidal ephithelium in some parts,and cubical in others. Each tube as it passes through the cortical substance, from the number of loops which surround and are connected with it, presents a pyramidal appearance; these are called the "*pyramids of Ferrein*," or lobules of the kidney. The total number of tubes is about two millions.

Arteries and Nerves.—The kidney is supplied by the renal artery, which divides into four or five branches as it enters the hilum. These again sub-divide into the *arteriæ propriæ renales*, which enter the kidney in the spaces between the papillæ (columns of Bertini). They here give off branches which supply the Malpighian pyramids, and cortical substance. Opposite the bases of these pyramids they make an abrupt bend, and give off branches (*arteriolæ rectæ*) which supply the interior of the pyramid, descending to the apex. They are then continued on between the "lobules," or pyramids of Ferrein, under the name of interlobular branches, until they reach the capsule. In their

course they supply the Malpighian bodies, giving them tufts as already described (Fig. 84). The afferent vessel after leaving the Malpighian body, joins the capillary plexus surrounding the tubuli uriniferi, and from this plexus arise the veins which return the blood. The circulation in the Malpighian bodies is therefore an off-set from the ordinary circulation, and in this respect resembles the *portal* circulation. The *nerves* of the kidney are derived from the solar plexus, the semilunar ganglia, and the lesser and smallest splanchnic nerves.

Sinus of the Kidney.—This is a large cavity in the interior of the kidney which communicates with the tubuli uriniferi on the one hand, and the ureter on the other. It consists of three prolongations, the infundibula, one situated at each extremity of the organ, and one in the middle. Each infundibulum is divided into from seven to thirteen smaller portions, the calyces, each of which surrounds, like a cup, the base of one or more of the papillæ. It is lined by spheroidal epithelium.

Secretion of Urine.—The secretion of urine from the blood is effected by the agency of cells. Some substances as urea, uric acid, etc., exist ready formed in the blood, and need only to be removed; but other substances, as the acid phosphates and the sulphates are formed by the agency of cells. It is probable, also, that the Malpighian bodies furnish chiefly the fluid portion of the urine, for it has been observed that in those animals which pass the urinary exerement in a semi-solid state, the tufts of the Malpighian bodies are very small. The secretion of urine is rapid, in comparison with other secretions. It passes down the ureters and enters the bladder drop by drop; this may be seen in some cases of *ectopia vesicæ.* Some substances pass very rapidly from the stomach through the circulation, to be eliminated by the kidney; *e.g*, a solution of potassium ferrocyanide passed in one minute, while some vegetable

substances as rhubarb, occupied from sixteen to thirty-five minutes. The transit is slower, when the substances are taken during digestion.

URINE.

Healthy urine is a clear, limpid fluid, of a pale straw or amber color, with a peculiar odor, and saline taste. When first voided, it has an acid reaction, but after a short time it becomes alkaline from the development of ammonia during decomposition. In some instances the urine may become turbid on cooling, although clear and transparent at first. The *specific gravity* varies from 1015 to 1025, depending on the time at which it is secreted, the kind of food, drink, etc. In consequence of this, the secretion has been divided into three varieties:—1st, *urina potus,* or that which is secreted after the introduction of fluids into the body; 2nd, *urina cibi,* or that secreted after the introduction of solid food; 3rd, *urina sanguinis,* or that secreted from the blood when neither food nor drink has been taken. For purposes of investigation, a portion of the urine passed during a period of twenty-four hours should be taken. In disease, as albuminuria, the specific gravity is diminished to 1004; while in diabetes it may be increased to 1050 or 1060. The quantity of solids in any given specimen of healthy urine may be determined approximately by doubling the last two figures of the *sp. gr.*; thus 1018, $(18 \times 2) = 36$ grains of solids in 1000 grains of the urine. The whole quantity of urine secreted in twenty-four hours varies, according to the amount of fluid drank, and the quantity secreted by the skin, from thirty to fifty ounces. The secretion of the skin is more active in warm weather than in cold, and consequently the quantity of urine secreted during winter is greater than in summer.

CHEMICAL COMPOSITION OF THE URINE.—The urine consists of water, holding in solution certain animal matters,

salts, coloring matters, etc. Its composition according to the most recent analyses is as follows, in 1000 parts.

Water	950.00
Urea	26.20
Uric and hippuric acids, combined with sodium, potassium and ammonium	2.15
Creatine, creatinine, mucus and coloring matter	1.22
Sodium and potassium chlorides	12.45
Sodium and potassium sulphates	3.30
Sodium, potassium, calcium and magnesium phosphates	4.28
Sodium bi-phosphate	.40
	1000.00

WATER.—The quantity of water varies in different seasons, and according to the drink, exercise, action of the skin, etc. In some diseases it is very much increased, as in hysteria, diabetes, etc. In other diseases, as albuminuria, diarrhœa and dysentery, it is very much diminished. In fevers, albuminuria, and in inflammation also, the quantity of water is almost invariably diminished.

UREA.—($C H_4 N_2 O$). This constitutes more than half of the solid matter of healthy urine. The quantity is increased by a purely animal or highly nitrogenous diet, and slightly by exercise. The increase of urea in active muscular exercise was formerly supposed to be in exact proportion to the amount of muscular exercise, but this has been found by experiment not to be the case; the waste of muscle cannot be expressed by the increase in urea. Urea exists already formed in the blood, and is simply removed by the kidneys. It is formed from the decomposition of the nitrogenous elements of the food, and from the disintegration of the azotized tissues. It may be readily obtained by evaporating urine to the consistence of honey, and acting on it with four parts of alcohol; then evaporating and crystallizing. It crystallizes in acicular crystals, which appear, under the microscope, as four-sided prisms, (Fig. 86). It is purified by filtering through animal charcoal. It may also be obtained in the form of urea nitrate ($C H_4 N_2 O H N O_3$), by evaporating urine to one-half, and then adding

an equal quantity of nitric acid, and crystallizing. Urea

Fig's 86 and 87.

Fig. 86. Crystals of urea. Fig. 87. Crystals of uric acid.

is identical in composition with ammonium isocyanate, ($NH_4CNO = CH_4N_2O$), and may be prepared artificially by the chemist, by double decomposition from potassium isocyanate, and ammonium sulphate. Urea is colorless when pure, and destitute of smell, neutral in its reaction to test paper, and soluble in water and alcohol. When urine stands for some time, the urea is decomposed, and forms ammonium carbonate. It is also decomposed, in some cases, before it leaves the bladder, as in paralysis, and some low forms of disease. An average of 500 grains (32.4 grammes) of urea are excreted from the body in twenty-four hours, when the kidney is in a healthy condition; but in some diseases, as, *e. g.*, in desquamative nephritis, Bright's disease, or congestion of the kidney from any cause, a certain portion of the urea is kept back, and circulating through the system may, by its poisonous effects on the cells, give rise to dropsies in different parts of the body, or from its deleterious effects on the nervous system, occasion uræmic convulsions and coma.

Uric or Lithic Acid ($C_5H_4N_4O_3$).—This substance is rarely absent from healthy urine. It is combined with sodium and ammonium in the form of urates. It predominates in the urinary excrements of birds, serpents, and other reptiles; while urea predominates in the mammalia, especially the *herbivora*. In the urine of the feline tribe, uric acid is sometimes entirely replaced by urea. Uric acid and urea are, therefore, closely allied to each other, and each alone may represent the excretion of the two. The quantity of uric acid, like that of urea, is increased by the use of animal or highly nitrogenized food, and decreased by

food which is free from nitrogen. It is increased in all febrile conditions, and in gout it is deposited in and around joints, in the form of sodium urate, and constitutes the so-called "chalk-stones." Uric acid has been detected in the blood of healthy persons, and in considerable quantity in gouty patients. It is supposed to be formed in the system from the disintegration of the azotized tissues. Uric acid may be readily obtained by adding a few drops of hydrochloric acid to a portion of urine in a watch glass; after a few hours it is found crystallized on the sides and bottom of the vessel. In larger quantities it may be obtained from the thick, white, urinary excrement of serpents or birds, which consists almost entirely of ammonium urate. This substance is dissolved in warm water, and then decomposed by nitric or hydrochloric acid. The crystals of uric acid assume very various and somewhat fantastic shapes, most frequently rhombic or diamond shaped (Fig. 87). It is insoluble in alcohol and ether. When the urates are in excess in the urine, they appear as a "brick-dust" sediment in the vessel. They may be distinguished from other deposits by their not appearing until the urine becomes cold, and by disappearing again entirely on the application of heat.

Hippuric Acid ($C_9 H_9 NO_3$.)—This acid exists in small quantity in human urine, probably in the form of sodium and potassium hippurates, but is very abundant in the urine of cows, horses and other herbivorous animals. It is closely allied to benzoic acid ($C_7 H_6 O_2$), and this substance when taken into the system, is excreted in the form of hippuric acid. Hippuric acid is chiefly formed from vegetable articles of food, and

Fig's 88 and 89.

Fig. 88. Crystals of hippuric acid. Fig. 89. Large prismatic crystals of triple phosphates, among which are seen some crystals of ammonium urate.

may be prepared from the urine of cows by precipitation with hydrochloric acid. It has a bitter taste, is slightly soluble in cold, but very soluble in hot water and alcohol.

Creatine—($C_4 H_9 N_3 O_2$) occurs in very small quantity in the urine. It is a colorless crystalline body, with a pungent taste, soluble in water, but almost insoluble in alcohol. It may be obtained from the flesh of animals. It is most abundant in the flesh of fowls, and in the heart of the ox.

Creatinine—($C_4 H_7 N_3 O$) is also found in the urine. It crystallizes in colorless crystals, has a hot, pungent taste like caustic ammonia, and is soluble in water and alcohol. It may be formed from creatine, by the action of hydrochloric acid, and is probably formed from creatine in the system.

Urochrome or *Urosacine*, the coloring matter of the urine, has been already described, (see proximate principles). A substance termed *Indican* has been found in the urine by several observers; by its decomposition indigo blue, and indigo red are produced.

The urine also contains a certain amount of mucus and epithelial debris from the mucous surface of the urinary passages.

Salts.—The salts of the urine constitute less than half of the solid ingredients. Sodium and potassium chlorides form a large proportion of the salines of the urine, the former being more abundant than the latter. They are derived in part from the food, and also partly from chemical decomposition within the body. They may be readily precipitated by a solution of silver nitrate after the urine has been acidulated by nitric acid. When silver nitrate is added to healthy urine, a whitish precipitate of silver chloride and sodium phosphate is thrown down; the latter may be dissolved by the addition of a little nitric acid. The silver chloride is readily dissolved by a little ammonia.

The *sulphates* are more abundant in the urine, than in the

fluids and tissues of the body. They are increased by exercise, and in diseases accompanied by muscular exertion, as in chorea and delirium tremens. They are also increased by the introduction of sulphur or the sulphides into the system. The sulphuric acid is formed by the oxidation of sulphur, which is derived from the decomposing albuminoid substances.

The *phosphates* are more numerous than the sulphates. Phosphorus is derived from the decomposition of nerve substance, albumen and fibrin, and like sulphur, is oxidized at the lungs, and then unites with the bases to form salts. The *alkaline phosphates,* or potassium and sodium phosphates are those salts by which most of the phosphoric acid is eliminated in the urine. They are readily soluble, and never appear as a precipitate in urine. The quantity of alkaline phosphates is increased by a diet of animal food; also by great mental exertion, and in phrenitis. They are also increased by exercise, while the earthy are diminished. The *earthy phosphates,* or calcium and magnesium phosphates, are not very abundant in the urine. They are held in solution by the sodium biphosphate, and when this is absent or neutralized they fall as a precipitate.

The *acid sodium phosphate,* or sodium biphosphate gives the urine its acid reaction. It is supposed to be formed from the ordinary sodium phosphate of the blood by the action of uric acid, which unites with a part of the sodium forming sodium urate, leaving an acid sodium phosphate. Though freshly voided urine exhibits an acid reaction, yet it has no *free* acid, but within a few hours after its discharge it undergoes the so-called *acid fermentation* resulting in the production of free lactic, and sometimes oxalic acid, formed from some of the organic ingredients. The latter when formed is precipitated with calcium, forming a sediment of calcium oxalate (Fig. 90). In a few days these changes

Fig's. 90 and 91.

Fig. 90 Crystals of calcium oxalate.
Fig. 91 Crystals of cystin.

cease, and are followed by the so-called *alkaline fermentation*, during which some of the phosphates are thrown down. This change is brought about by the decomposition of urea and its transformation into ammonium carbonate. This causes a precipitation of the earthy phosphates which unite with some of the ammonium, and are deposited in the form of ammonio-magnesium phosphate (triple phosphate) Fig. 89. The urine at this time has a strongly ammoniacal odor. Cystin (Fig. 91), is occasionally found in unhealthy urine.

MAMMARY GLANDS AND THEIR SECRETION.

These are the organs which secrete the milk. They are large and hemispherical in the female, but are quite rudimentary in the male. They are situated in front of the pectoralis major, between the third and sixth ribs, and extend from the sides of the sternum nearly to the axillæ. They are enlarged at puberty, increased during pregnancy and lactation, and diminished in old age. The outer surface of the mamma presents a little below the centre, a small conical eminence—the nipple—the surface of which is dark-colored, and surrounded by an areola, which has a rosy hue in the virgin, but becomes very dark-colored during pregnancy. Its summit is perforated by numerous openings, the orifices of the lactiferous ducts. It is also provided with a number of sebaceous glands, situated near its base and upon the surface of the areola, which secrete a peculiar fatty substance for the protection of the nipple during sucking. The nipple consists of numerous blood-vessels, nerves, lymphatics, ducts, erectile tissue, and nonstriated muscular fibre-cells, and is capable of slight erection during sexual excitement or irritation.

Structure.—The mamma consists of numerous lobes, which are made up of small lobules, connected together by areolar tissue, blood-vessels and ducts. There is also some adipose tissue between the lobules. Each lobule, which is a representation of the whole gland, consists of a cluster of rounded vesicles, which open into the smallest branches of the lactiferous ducts, and these, uniting, form larger ducts —the tubuli lactiferi. These vary in number from fifteen to twenty, and converge towards the areola, beneath which they form dilatations, or *ampullæ,* which serve as reservoirs for the milk; they then become contracted, and continue onwards to the summit of the nipple, where they open by separate orifices, which are narrower than the ducts themselves. The entire surface of the gland is invested by fibrous tissue, from which numerous septa are derived, which pass between the lobes.

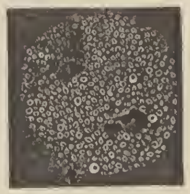
Milk.—The secretion of milk is usually limited to the period succeeding parturition, yet this is not invariably the case. Numerous instances are on record where young women who have never borne children, and even old women, have been able to act as wet nurses. In some rare cases, the male has been known to secrete milk in the breasts. A fluid resembling milk, may frequently be expressed from the mammary glands of infants. Milk has an alkaline reaction, and the specific gravity varies from 1020 to 1030. The specific gravity alone is of no value as an indication of the richness of the milk. The average *chemical composition* of human milk is as follows, in 1000 parts:

Water	890
Butter	26
Casein and Extractive	40
Lactose	42
Fixed Salts	2
	1000

When milk is examined with a microscope, a large number of minute particles may be seen, termed "milk globules,"

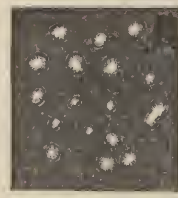
which vary in size from $\frac{1}{3000}$ to $\frac{1}{12000}$ of an inch (8.3 to 2 mmm) in diameter. They are coated with albuminous

Fig. 92.



Oil globules of human milk.

Fig. 93.



Oil globules of cow's milk.

matter, and are soluble in ether and alkalies. In the *colostrum*, or first milk secreted after labor, large, yellow, granulated bodies may be seen, called *colostrum corpuscles.* They are supposed by some to be exudation corpuscles; others regard them as transformations of the epithelial cells of the gland, containing fatty matter. The colostrum has a purgative effect on the child, which is useful in clearing the bowels of the meconium which they contain at birth. The *oleaginous matter* of milk chiefly consists of the ordinary constituents of fat, together with a substance called "butyrin," to which the taste and smell of butter are due. When this substance is treated with alkalies, or suffers decomposition, the following volatile acids are produced, viz.; butyric, caproic, caprylic, and capric (rutic.) These are called butter acids.

The *casein* of human milk is not so readily precipitated as cow's milk. It requires a large amount of acid, and rennet does not seem to take effect upon it, unless an acid be present. The casein of asses' milk bears a closer resemblance to that of human milk, than does that of the cow. The best substitute for human milk, however, is cow's milk diluted with water, and a little sugar added.

Lactose or *milk sugar* (C_{12} H_{24} O_{12}), may be obtained from whey by evaporation and crystallization. It strongly resembles *glucose*, into which it may be converted by the addition of dilute sulphuric or hydrochloric acid. The action of a ferment causes lactose to undergo the lactic acid fer-

mentation; and when lactic acid, or calcium lactate is allowed to stand for some time, it is changed into butyric acid, or calcium butyrate, having undergone the "butyric acid fermentation."

The *saline matter* of the milk is nearly identical with that of the blood, with an increase in the calcium and magnesium phosphates. From what has been already stated, it will be observed that milk contains the four classes of principles which are required for human food, viz: The *aqueous*, the *albuminous*, the *oleaginous*, and the *saccharine*, consequently it is well adapted to the nourishment of the young animal. From 20 to 40 ounces of milk are secreted in 24 hours. Stimulating liquors often used to incre se the quantity of milk, seldom act otherwise than prejudicial.

Certain medicinal agents, when administered to the mother, may pass into the milk, and in this way affect the child. As a rule, salines pass more readily than vegetable substances. Medicine may be administered to the mother, instead of the child, when it is desired to act upon the latter.

Emotions of the mind, as anger, grief, fear, etc., produce peculiar changes in the quantity and quality of the milk; for example, anger produces very irritating milk, which causes griping in the child, and green stools. Grief diminishes the secretion, and frequently vitiates it. Fear also diminishes the secretion, and that which is secreted under such circumstances is highly irritating. Violent exercise, or great anxiety of mind, has also a bad effect on the secretion of milk. Cases are recorded in which children have had convulsions, and died shortly after sucking milk secreted under the foregoing circumstances.

CHAPTER XII.

DUCTLESS OR VASCULAR GLANDS.

These are so named from having no excretory ducts; they are the *spleen, supra-renal capsules, thymus* and *thyroid* glands. They contain the same essential structures as the secreting glands, except the ducts. They are highly vascular, and are concerned in the elaboration of the blood. Their function, however, does not seem essential to life. They may become atrophied, or be removed from animals, without any serious consequences.

SPLEEN.

The *spleen* is situated in the left hypochondriac region, embracing the cardiac end of the stomach. It is of an oblong shape, highly vascular, very brittle, and of a bluish-red color. It measures five inches in length, three or four in breadth, and one and a half in thickness, and weighs from four to six ounces.

STRUCTURE.—It is invested by two coats, an *external serous* and an *internal fibrous elastic* coat. The *serous coat* is derived from the peritoneum, and is intimately adherent to the fibrous coat. It covers nearly the whole organ, being reflected from it at the upper end on to the diaphragm forming the suspensory ligament, and at the hilum on to the great end of the stomach, forming the gastro-splenic omentum. The *fibrous coat* consists of white fibrous and yellow elastic tissue. It covers the exterior of the organ, and sends prolongations inwards at the hilum, in the form of vaginæ or sheaths, which surround the vessels. From these sheaths, and from the inner surface of the fibrous coat, numerous trabeculæ or bands pass in all directions, and these uniting

form the areolar framework of the spleen. The presence of the elastic tissue, permits of the great enlargement of this organ which is sometimes seen. The spaces or areolæ between the bands are filled with a soft pulpy mass, of a dark reddish-brown color, consisting of *colorless* and *colored* elements—the proper substance of the spleen, or *spleen pulp*—and some rounded bodies the Malpighian corpuscles.

The *colorless elements* form about one-half or two-thirds of the entire pulp, especially in well-fed animals, and consist of granular plasma, free nuclei, about the size of red blood corpuscles, and a few nucleated lymphoid cells. The *colored elements* consist of unchanged red blood corpuscles, and blood discs in various stages of decay. Besides these, may be seen a number of granular bodies or crystals, which in chemical composition resemble the coloring matter of the blood.

The *Malpighian corpuscles* are rounded bodies from $\frac{1}{30}$ to $\frac{1}{60}$ of an inch (.8 to .4 mm) in diameter, of a semi-opaque whitish color, and are more distinct in early life than in adult age. Each consists of a membranous capsule, homogeneous in structure, and formed by a prolongation from the sheath of the small arteries to which it is attached. They are surrounded and embraced by the radicles of the arteries, and present a resemblance to the buds of the moss rose. Each capsule contains a soft white substance, consisting of granular plasma, nuclei, and nucleated lymphoid cells similar to the colorless elements

Fig. 94.

Branch of the splenic artery, showing the Malpighian corpuscles.

of the pulp. Small capillaries pass into their interior and form a minute plexus.

The *splenic artery* is large in proportion to the size of the gland, tortuous in its course, and divides into from four to six branches, which enter the hilum. Each branch runs transversely from within outwards, and divides into smaller branches; these ultimately terminate in tufts or pencils, which lie in contact with the pulp. The most striking peculiarity is, that each of the larger branches supplies chiefly that part of the organ to which it is distributed, having no anastomosis with the adjoining branches. The *capillaries* terminate either directly in the veins, or open into cæcal or lacunar spaces, from which the veins arise. The *veins* arise either in the ordinary way from the capillaries or by communicating intercellular spaces, or distinct cæcal pouches. They are much larger and more numerous than the arteries, and by their junction form from four to six branches which emerge at the hilum, and uniting form the splenic vein, the largest branch of the portal. From this it will be seen that the blood returning from the spleen passes through the liver before it enters the general circulation.

FUNCTION OF THE SPLEEN.—In consequence of the vascular arrangement and the large amount of elastic tissue which this organ contains, it is liable to undergo great changes in volume. Enlargement of the spleen is apt to occur from internal venous congestion, such as occurs in the cold stage of intermittent fever. When intermittent fever is long-continued, the spleen is generally very much enlarged, constituting what is commonly called "ague cake."

It was formerly supposed to act as a *diverticulum* of the liver, relieving its vessels from undue turgescence and preventing congestion of the liver, stomach and bowels; and also that it promoted the disintegration of the red blood corpuscles; but these views cannot be accepted in the present state of our knowledge. The spleen is

larger four or five hours after food is taken, and contains a larger proportion of finely granular albuminous material, than at any other time, therefore it is supposed that this organ is the receptacle for the increased quantity of albuminous material of the food, and which cannot be admitted into the system generally, without danger, until the volume of the circulating fluid has been reduced by secretion. In support of this theory, it has been stated that animals from which the spleen has been removed, are very liable to die of apoplexy, after taking large quantities of food. It would therefore appear to be a storehouse of nutrient material, which may be drawn upon as the system requires. The increase of the fibrin in the splenic vein would show that the nutrient material is elaborated during its withdrawal. It is also supposed to form the germs of future blood corpuscles, as there is found to be a large increase of the colorless corpuscles in the blood of the splenic vein.

SUPRA-RENAL CAPSULES.

The supra-renal capsules are situated one upon the upper extremity of each kidney, somewhat triangular in shape, the base being applied to the kidney, and the apex directed upwards. Each gland is about one and one-half to two inches in length, rather less in width, about one-fourth of an inch in thickness, and weighs from one to two drachms.

STRUCTURE.—Like the kidneys, they are divided into a *cortical* and *medullary* portion. The *cortical portion,* which forms the principal part of the organ, is of a deep yellow color, and consists of narrow, columnar masses, arranged perpendicularly to the surface, and held together by areolar tissue. These columnar masses measure about $\frac{1}{700}$ of an inch (35 mmm) in diameter, and consist of oval spaces or parallel tubes, containing a finely granular plasma, a mass of nucleated cells with large nuclei, and oil globules. The *medullary substance* consists of areolar tissue, containing a

plexus of minute veins, having stellate or polygonal granular cells in its meshes. It is soft and pulpy, very dark in color, hence the name *atrabiliary substance*, sometimes given to it. These glands are more highly supplied with nerves than any other glands in the body.

FUNCTION.—Very little is known regarding their function. They were formerly supposed to be the diverticula of the kidney. They are probably concerned in elaborating some of the materials of the blood. They are developed at an early period in fœtal life, and are larger than the kidneys ; but afterwards relatively diminish. It was observed by Addison that disease of the supra-renal capsules was associated with anemia, general weakness, and a peculiar change of color in the skin, the patient resembling a mulatto. The disease is called *morbus Addisonii*.

THYMUS GLAND.

This is only a temporary organ. It reaches its largest size at the end of the second year, and then declines until puberty, when only a small part remains. It is situated partly in the anterior mediastinum, and partly in the neck, extending from the lower border of the thyroid gland to the fourth costal cartilage. It is somewhat oval in shape, of a pinkish grey color, lobulated on its surface, and consists of two lobes. It is about two inches in length, one and a half in breadth, three or four lines in thickness, and weighs about half an ounce.

STRUCTURE.—Each lobe consists of a central cavity or reservoir, around which are arranged numerous lobules, held together by delicate areolar tissue. The lobules vary in size from a pin's head to a pea, and each contains a small cavity from $\frac{1}{18}$ to $\frac{1}{50}$ of an inch (1.4 to .5 mm) in diameter, which communicates with the central cavity or reservoir of the organ. Each lobule is surrounded by smaller or secondary lobules or acini, the cavities of which communicate with those of the primary lobules. If the capsule and areolar

tissue holding the parts together be dissected off, the gland may be drawn out into a tubular cord, around which the lobules are arranged in a spiral manner. The closed cavity of the organ, and the secondary lobules or *acini* contain a chyle-like fluid, consisting of nucleated corpuscles, granular nuclei and lymphoid cells.

FUNCTION.—This organ would appear to be connected with the preparation of matter for the pulmonary arteries in early life. In ill-nourished children the corpuscles become filled with fat, which is supposed to be added to the blood.

THYROID GLAND.

The thyroid gland is situated at the upper part of the trachea, and consists of two lobes connected by a narrow band (the isthmus), which crosses the second and third rings. Each lobe is conical in shape, about two inches in length, and three-quarters of an inch in breadth, the right being the larger. The whole gland weighs from one to two ounces. It is of a brownish-red color, larger in females than in males, and is increased during menstruation. It is occasionally very much hypertrophied, and constitutes *bronchocele* or goitre. In some countries, as in Switzerland and Northern Italy, bronchocele is very prevalent in both sexes. The children of goitrous parents are dwarfish, very defective in mental and moral faculties, and are known as *cretins*.

STRUCTURE.—In structure it consists of lobules, held together by areolar tissue. Each lobule consists of a number of closed vesicles, oblong or spherical in shape, each containing an albuminoid plasma, consisting of granules, oil globules, nuclei, and nucleated cells, the latter occupying the position of an epithelium within the vesicles. There is also some colloid substance, which is most abundant in enlargement of the gland. The vesicles vary in size from $\frac{1}{85}$ to $\frac{1}{2000}$ of an inch (300 to 12 mmm) in diameter.

Function.—The thyroid gland is supposed by some to act as a diverticulum of the cerebral circulation. When the brain is inactive, the thyroid gland takes on an increased action, and accommodates the blood that would otherwise go to that organ. This view is based on the fact that the arteries which supply this gland arise in close proximity to those which supply the brain. The vesicles also probably remove, and store up from the blood, certain constituents which are not required in its passive state, to be returned to it when it resumes its activity.

CHAPTER XIII.

THE NERVOUS SYSTEM.

The nervous system consists of two portions, the *cerebro-spinal*, and the *sympathetic* or *ganglionic* system. The former was distinguished by Bichat as the *nervous system of animal life;* the latter as the *nervous system of organic life.*

The *cerebro-spinal system* includes the brain and spinal cord, the nerves associated with them, and their ganglia, viz.:—The ganglia of the posterior root of the spinal nerves, the ganglion of the fifth nerve, and those of the glosso-pharyngeal and pneumogastric nerves. It includes the nervous organs in and through which are performed the several functions with which the mind is more immediately connected, as those relating to common sensation, volition, and the special senses, as well as those concerned in many nervous actions with which the mind has no connection.

The *sympathetic or ganglionic system* consists of a double chain of ganglia connected by nervous cords, which

extend along each side of the vertebral column, from the cranium to the pelvis, and from which nerves, with ganglia upon them, proceed to the viscera in the thoracic, abdominal, and pelvic cavities. This system is more closely connected with the process of organic life than the cerebro-spinal, but is less immediately connected with the mind.

In the lower orders of the animal creation, the nervous system is quite rudimentary. In the ascending series of animal life, it is first found in the medusæ or jelly-fishes. The ganglionic centres are situated around the free margin of the swimming bell. In these animals also, is seen the earliest appearance of muscular tissue in the animal kingdom. In its lowest and simplest form it may consist of single ganglionic centres, with *sensory* or *afferent*, and *motor* or *efferent* nerves (Fig 104), whose function is essentially internuncial, impressions being made and responded to without any intervention of consciousness, the movements being purely excito-motor. A simple repetition of such ganglionic centres may exist to any extent without dissimilarity of function, or any essential departure from the mode of action just mentioned. A higher form of nervous system is that in which there is a multiplication of ganglionic centres to correspond with the diversity of functions, as in the higher articulata and mollusca, in which ganglionic centres are set apart for the actions of deglutition and respiration, as well as for those of motion, but their *modus operandi* is still the same—the actions being all excito-motor. In all but the very lowest invertebrata, the nervous system includes, in addition to the above, certain ganglionic centres which preside over the organs of sight, smell, hearing, etc. These sensorial ganglia constitute the "brain" in these animals. The highest degree of psychical perfection, as in the class of insects, consists in the exclusive development of the *instinctive faculty*, or of simple automatic powers, by virtue of which each individual performs those actions to which it is prompted by impressions

made upon its afferent nerves, without any self-control or self-direction, so that it may be regarded as entirely a creature of necessity.

In the vertebrated series, on the other hand, the highest degree of psychical perfection, as shown in man, consists in the highest development of the *reason* and the supreme domination of the *will*, to which all the automatic actions—except those which are essential to the organic functions—are subject, so that each individual becomes not only a thinking and reflecting, but also a self-moving and self-controlling agent, whose actions are performed with a definite purpose in view. During the early period of life, however, the mental faculties are but little in advance of those of the higher invertebrata; for example, the infant is prompted to seize the nipple, not from any knowledge gained by experience, that by so doing it will relieve the feeling of hunger, but in consequence of the impulse arising out of impressions made upon the afferent nerves. The super-addition of more elevated endowments in the vertebrated series is coincident with the addition of a peculiar ganglionic centre, the *cerebrum*, to the sensori-motor apparatus.

The superiority of the mind of man over the lower animals consists not only in the greater variety and wider range of his faculties; but also in that dominant power of the will which enables him to utilize them with the highest effect. When the thoughts and feelings of man are the mere result of the action of external impressions upon a respondent organism, he may be considered irresponsible for his actions, his character having been formed *for* him, and not *by* him. But, whenever he can exert a volitional power of directing his thoughts and controlling his feelings, he is morally and intellectually responsible for his acts. Some persons, however, in consequence of the weakness of their will, are so much accustomed to act directly upon the prompting of any transient impulse, that they can scarcely be said to be voluntary agents; and others allow certain

dominant ideas or habitual feelings to gain such a mastery over them as to usurp for the time the power of the will.

The fundamental part of the cerebro-spinal system is the *cranio-spinal axis,* which consists of the spinal cord, medulla oblongata, and the sensory ganglia, the latter consisting of those ganglia lying along the base of the skull in man, and in which the nerves of the *special senses* have their origin, viz., the corpora striata and quadrigemina, the thalami optici, etc. This cranio-spinal axis, which represents the whole nervous system of the invertebrata (except the rudimentary sympathetic they possess), exists without any super-addition in the lowest known vertebrated animal, as in the case of the little fish called the amphioxus. This condition may even be found in the human species, as in the case of acephalous infants, in which neither the cerebrum nor cerebellum is present; such have existed for several days, breathing, sucking, crying, and performing various other actions.

In man, however, and in all the higher vertebrata, large ganglia, which form the principal mass of the encephalon, are found superimposed upon and embracing the sensory ganglia. These are the *cerebrum* and *cerebellum;* the former is the seat of the will, and presides over, controls, and regulates all the actions and movements of the body, except the organic functions and excito-motor actions; the latter is concerned in the regulation and co-ordination of the actions of the spinal cord. The action of the cerebro-spinal system may be elucidated by the following diagram —Carpenter.

Intellectual operations— ——+ The Will ——
\+ Emotions. ——+ Cerebrum.
Centre of emotional and ideo-motor reflexion.
\+ Ideas.
\+ Sensations——+ Sensory ganglia——+
Centre of sensori-motor reflexion.
\+ Impressions——+ Spinal Cord——+
Centre of excito-motor reflexion.
\+ Motor Impulse.

In consequence of the peculiar arrangement of the nervous apparatus, excitor impressions travel in the upward direction; so in the left-hand corner of the diagram the *impressions* are represented as passing upwards. If they meet with no interruption, they travel upwards through the spinal cord until they reach the sensorium or sensory ganglia, where they make an impression on the consciousness of the individual, giving rise to *sensations*. These, passing from the sensory ganglia to the cerebrum, form *ideas*. If these ideas are associated with feelings of pain or pleasure, they give rise to *emotions;* and either as simple or emotional ideas, they become the subject of *intellectual operations* whose final issue culminates in an act of the *will*, which may be exerted in producing or checking a muscular movement, or in controlling or directing the current of thought.

If this ordinary upward course be interrupted, or if the action be excito-motor, the impressions will exert their power in the transverse direction, and a *reflex action* will be the result; for example, if the interruption be produced by division or injury of the spinal cord, below the sensory ganglia, reflex movements being produced without sensation will be purely excito-motor. So, again, if the connection between the sensory ganglia and the cerebrum be severed, or if the function of the cerebrum be in abeyance, they may react on the motor apparatus by the reflex power of the sensory ganglia themselves; such actions, being dependent on the promptings of sensation, are sensori-motor.

The afferent and efferent nerves, and their connection with the spinal cord, constitute an excito-motor *nerve arc*, and the spinal cord consists of a longitudinal series of excito-motor arcs, since an impression may be made through the afferent nerve which produces action of the muscles supplied by the efferent nerve, the whole being consumed without leaving behind any impression on the nervous centre. The nerve arc may be connected to a ganglion by means of a band or

commissure, through which a portion of the nervous influence passes to be stored up. This is called a *registering ganglion*, as, for example, the corpus striatum, thalamus opticus, etc., and these, in their turn, are connected to the cerebrum, this connection constituting what is called the *influential arc.* The registering ganglia are regarded as the sensorium, and correspond with the sensory ganglia. Their function appears to be to receive and retain impressions of ideas, events or occurrences, the time, place, and order in which they occurred, and other circumstances which are usually ascribed to the faculty of memory.

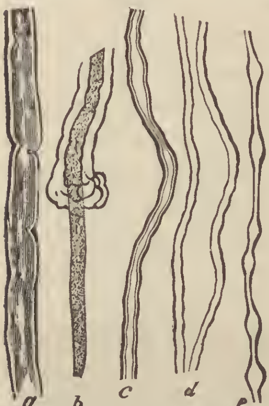
STRUCTURE OF THE NERVOUS SYSTEM.—The organs of the nervous system are composed essentially of two different elements, *nerve fibres* and *nerve cells.* The former, on account of their color, are often called the *white* or medullary substance; the latter, the *gray* or cineritious substance.

NERVE FIBRES.—There are two different kinds of nerve fibres, the *medullated* and the *non-medullated.* They are intermingled in most nerves, the former being more numerous in the cerebro-spinal system; the latter predominating in the sympathetic.

The *medullated nerve fibres* consist of tubules of simple homogeneous membrane, the *neurilemma*, similar to the sarcolemma of striated muscular tissue, within which is contained the proper nerve substance, consisting of two different materials. The central part consists of a greyish material called the *axis cylinder;* the outer portion which surrounds the axis cylinder is usually opaque, and dimly granular, and is called the *white substance of Schwann.* It is the predominance of this substance which gives the cerebro-spinal nerves their white appearance. The axis cylinder consists of a large number of primitive fibrillæ, and is the conductor of nerve force. It is the essential element of the nerve tube, and may be compared to the "core" of the submarine cable; the white substance of Schwann to

the insulating layer of gutta-percha, and the tubular membrane or sheath, to the outer coating of rope, merely affording mechanical protection, and serving to isolate it from the neighboring fibres. The axis cylinder is readily stained with carmine, the white substance of Schwann remaining unaffected; while chromic acid renders the latter brown and opaque, but has no action on the former. In the recent state the nerve tubes are cylindrical, and contain a transparent and apparently homogeneous material, but after death they present a dark double contour, the outer line being formed by the tubular membrane or sheath, the inner by the white substance of Schwann. At the same time the white substance and axis cylinder, which now appear granular, collect into little masses which distend portions of the tubular membrane, while the intermediate spaces collapse, giving the fibres a varicose or beaded appearance. The contents of the nerve tubes are very soft, and readily pass from one part of the canal to another, or escape from the ends of the tube on pressure. The nerves vary in size from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch (12. to 8. mmm) in diameter in the trunk and branches of nerves, but are smaller in the gray matter of the brain and spinal cord, in which they are seldom more than $\frac{1}{10000}$ to $\frac{1}{12000}$ of an inch (2.5 to 2 mmm).

Fig. 95.



Medullated nerve fibres; a, broad fibre; b, torn fibre with axis cylinder protruding; e, fibre of medium width; d, e. fine fibres.

Non-medullated nerve fibres constitute the olfactory nerves, the principal part of the trunk and branches of the sympathetic, and are mingled in various proportions in the cerebro-spinal nerves. They differ from the medullated nerves in their fineness, being only one-half or one-third as large ($\frac{1}{4000}$ to $\frac{1}{6000}$ an inch, 6 to 4 mmm); in the absence of the double

Fig. 96.

Sympathetic nerve fibres, b, b, among which are seen two dark bordered nerve fibres, a.

contour; in their apparently uniform structure, and yellowish gray color. These fibres consist of the sheath and the substance which corresponds with the axis cylinder of the medullated nerves, and differ from them in not possessing the white substance of Schwann. In the finer divisions of nerve fibres the axis cylinder is frequently found without any covering whatever.

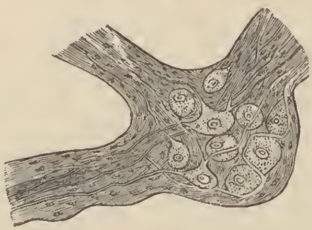
NERVE CELLS.—*Nerve cells* or *ganglion corpuscles* are found in the brain, spinal cord, and the various ganglia mingled with nerve fibres, being imbedded in a fine stroma of retiform tissue called the *neuroglia*, and give to these structures a peculiar reddish-gray color. They present different shapes, some being spheroidal or *apolar*, others caudate or *unipolar*, and others *bipolar*, *multipolar* or stellate, some of the processes being continuous with a nerve fibre. They vary in size from $\frac{1}{300}$ to $\frac{1}{10000}$ of an inch (83 to 2.5 mmm) in diameter. Each cell contains a vesicular nucleus, and nucleolus, the latter being generally clear and bright; and the contents are finely granular, and of a reddish gray color.

Fig. 97.

Nerve cells; *a*, apolar; *b*, unipolar; *c*, *c*, multipolar cells.

Ganglia.—These may be regarded as separate and independent nervous centres, of smaller size than the brain, and less complex. They are found on the posterior roots of the spinal nerves; on the posterior root of the fifth nerve; on the facial, olfactory, glosso-pharyngeal and pneumogastric nerves; along the base of the brain, as the corpora striata, corpora quadrigemina and thalami optici; on each side of the vertebral column forming the trunk of the sympathetic, and on some of its branches of distribution. In *structure* they are similar to other nervous centres, being composed of a collection of nerve cells, and medullated and non-medullated nerve fibres. They are of a reddish-gray color.

Fig. 98.

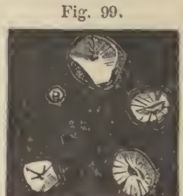


A nerve ganglion, showing the arrangement of nerve cells and nerve fibres.

Chemical Composition of Nerve Tissue.—Nervous matter of the brain is a soft, unctuous substance, easily lacerated, and contains about 75 per cent. of water, 15 parts of fatty matter, 7.5 of albuminous compounds, 1.5 of salts, and 1 of extractive matter. The fatty matter is more abundant in the white than in the grey substance. Among the albuminous substances are to be found, cerebrin, lecithin myosin, creatin, xanthin etc. From the fatty matters may be obtained carbonic acid, cholesterine, phosphoric and oleophosphoric acids, traces of oleine, margarine, and fatty acids. The quantity of phosphorus is very large. The spinal cord is said to contain a larger proportion of fat than the brain.

Corpora Amylacea.—These are small, rounded bodies, identical with starch granules, from $\frac{1}{4700}$ to $\frac{1}{1100}$ of an inch (5.5 to 22.5 mmm) in diameter, which are found in the fornix, septum lucidum and lateral ventricles of the brain. They are transparent, soft, irregularly rounded and present a star-

Fig. 99.



Corpora amylacea.

shaped pore with a faint laminar arrangement. They give a blue color when treated with iodine and sulphuric acid. The physiological relations of these bodies are not known.

Distribution of Nerve Fibres.—Nerve fibres consist of round or flattened cords, communicating on the one hand with the nervous centres, and on the other distributed to the various textures of the body, forming the medium of communication between the two. They are divided into *two* great classes, the *cerebro-spinal*, or nerves of animal life, distributed to the organs of the senses, the skin, and the muscles; and the *sympathetic* or nerves of organic life, distributed chiefly to the viscera, and blood-vessels.

The *cerebro-spinal nerves* consist of a number of primitive nerve fibres, enclosed in a simple membranous sheath. These are called funiculi, and if the nerve is of small size it may consist of only one funiculus; but if large, there may be several connected together by a common sheath formed of areolar tissue. Every nerve fibre pursues an uninterrupted course from its origin at a nervous centre, to its destination, whether this be the periphery of the body, in another nervous centre, or the same from which it issued. They anastomose or communicate with each other in their course, sometimes joining at acute angles with others proceeding in the same direction; but they never coalesce, or unite with the substance of any other fibre; for although they cross and mingle with each other, yet each separate nerve fibre retains its identity throughout. The nerves, in certain parts of their course, form *plexuses* in which they anastomose with each other, as in the cervical, brachial, lumbar, and sacral plexuses. In the formation of a plexus, the component nerves divide, then unite, and again sub-divide, and in this way the fasciculi become intricately interlaced. The object of such interchange of fibres is to give each nerve a wider connection with the spinal cord, so that the parts supplied may have

wider relations with the nervous centres, and also that groups of muscles may be associated for combined action.

ORIGIN AND TERMINATION OF NERVES.—The point of connection of a nerve with the brain, spinal cord, or ganglion is called, for convenience of description, its *origin*, *root*, or *central termination;* the point of distribution its *peripheral termination*, or *periphery*.

With reference to their *origin*, some of them originate in *nerve corpuscles*, or their prolongations, others probably form *simple loops*. As the nerve fibre approaches the nerve corpuscle or its prolongation, the white substance of Schwann gradually disappears, the tubular membrane or sheath blends with the nerve corpuscle, and the axis cylinder becomes continuous with the contents of the cell. More fibres have been counted leaving than entering a ganglion, from which it may be inferred that some of them arise from the corpuscles. It has not yet been determined whether this relation of nerve fibres to nerve corpuscles is common to all kinds of nerve fibres. Some are of opinion that sensitive fibres alone are brought into this intimate relation with nerve corpuscles. It does not appear, however, to belong exclusively to either the cerebro-spinal or sympathetic nerves.

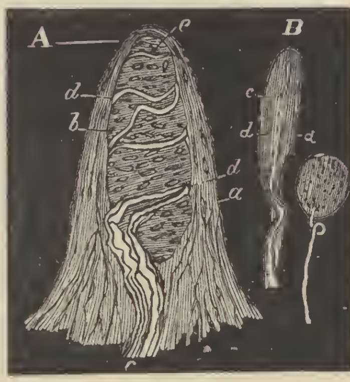
The *peripheral termination* is also exceedingly difficult to determine, but examples of *five* different modes have been observed.

1st. In *loops* or *plexuses*. In this mode of termination, each fibre, after issuing from a branch in a terminal plexus, runs over or through the substance of the tissue; it then turns back and joins the same, or an adjacent branch, and pursues its way back to the nervous centre. This mode has been found in mucous and serous membranes, in the anterior epithelium of the cornea and in muscular tissue.

2nd. In *terminal bulbs*, called *tactile corpuscles* of Meissner and Wagner, (Fig. 100 A); *end-bulbs of Krause*, (Fig. 100 B); and *Pacinian bodies*, or corpuscles of Vater (Fig. 101.) The *tactile corpuscles* are oval shaped bodies, formed

of delicate connective tissue, around which the nerve passes in a spiral manner. They are found in the papillæ of the skin, especially in the palms of the hands and the soles of the feet. Their length is about $\frac{1}{250}$ and their thickness $\frac{1}{500}$ of an inch (100 to 50 mmm). The *end-bulbs of Krause* resemble the tactile corpuscles in appearance, but are smaller and more simple in structure. They form a round or oval enlargement homogeneous in structure, at the extremity of the nerve, and are found in the conjunctiva, floor of the mouth, the tongue, the glans penis, and the clitoris.

Fig. 100.



A. Cutaneous papilla of the hand; (*a*,) cortical layer with cells and elastic fibres; (*b*) tactile corpuscle ; (*c*, *d*) nerve fibres. *B.* End bulbs of Krause; (*a*) covering of nerve bulb ; (*d*) interior of bulb ; (*c*) nerve fibre.

Fig. 101.

A Pacinian corpuscle. 1, base; 2 apex; 3, 3, substance of the corpuscle, in layers; 4, 4, nerve penetrating the corpuscle; 5, cavity of the corpuscle; 6, nerve; 7, nerve, which has lost its medullary substance and sheath; 8, termination of the nerve; 9, granular substance continuous with the nerve. (Sappey.)

The *Pacinian corpuscles* are small oval bodies, situated on some of the the cerebro-spinal and sympathetic nerves, especially the cutaneous nerves of the hands and feet. They are named after their discoverer Pacini. They are most distinctly seen in the mesentery of the cat. Each corpuscle is attached to the nerve on which it is situated by a narrow pedicle, and is formed of concentric layers of fine membrane, with intervening spaces filled with fluid. A single nerve fibre passes through the pedicle, and after traversing the

several layers of membrane, it terminates in the central cavity in a bulbous enlargement, or a bifurcation (Fig. 101). The function of these bodies is not known; they are probably reservoirs for nerve force.

3rd. In *motorial end-plates*, as described by Rouget and others. This is the mode of termination in striated muscular tissue. As the nerve fibre approaches the muscular fibre it expands, the sheath blends with the sarcolemma, the white substance of Schwann terminates abruptly, and the axis cylinder spreads out beneath the sarcolemma on the surface of the fibrillæ, forming an oval plate from $\frac{1}{500}$ to $\frac{1}{1000}$ of an inch (50 to 25 mmm) in diameter (Fig's 38 and 102).

Fig. 102.

Termination of a nerve fibre by a motorial end-plate in a muscular fibre (Longet.)

4th. Some nerves appear to terminate *in cells*, or nerve corpuscles, as those of the eye, interal ear and other parts.

5th. In *free ends* as from the fine plexuses in non-striated muscular tissue, and in the cornea.

Some nerve fibres appear to have no peripheral termination. It has been shown by Gerber that nerve fibres occasionally form loops by their junction with a neighboring fibre in the same fasciculus, and return to the nervous centre without having any peripheral termination. He considers these to be sentient nerves, for the supply of the nerve itself, the *nervi nervorum*, upon which the sensibility of the nerve depends. This is somewhat similar to those nerve fibres met with at the posterior part of the optic commissure, where a set of fibres pass from one optic tract across the commissure to the tract on the

Fig. 103.

The optic commissure.

opposite side, without having any connection with the optic nerves—the inter-cerebral fibres; others appear to have no central connection with the cerebro-spinal centre, as those forming the anterior fibres of the optic commissure—the inter-retinal fibres. These commence in the retina on one side, pass along the optic nerve, and across the commissure to the retina of the opposite side.

Medullated nerve-fibres lose the white substance of Schwann, before their final distribution, and bear a close resemblance to the non-medullated fibres.

The *sympathetic nerves* consist of medullated and non-medullated fibres, intermingled in various proportions in different nerves, and are enclosed in a sheath of areolar tissue. The mode of distribution of these nerves is essentially the same as that of the cerebro-spinal. The most striking peculiarity is the frequent formation of ganglia in the course of the trunk and their branches. They are chiefly distributed to the head and trunk, being very limited in their connection with the extremities.

FUNCTION OF NERVE FIBRES.—The functions of nerve fibres and nerve centres are determined by comparing their *anatomy in man* with that of the lower animals; by *experiments* on recently-killed or living animals, and by *clinical observation.*

The office of the nerves is to convey or conduct nervous impressions. The function is of a two-fold kind—*first,* they serve to convey to the nervous centres the impressions made upon their peripheral extremities, or on parts of their course; and, *secondly,* they serve to transmit impressions from the brain, and other nervous centres, to the parts to which they are distributed. These impressions are of two kinds, viz., those that excite muscular contraction, and those which influence the processes of secretion, growth, etc.

Those nerves that convey impressions from the periphery to the centre, are called *sensitive, centripetal* or *afferent* nerves, or *nerves of sensation;* and those which transmit im-

pulses to the muscles, are called *motor, centrifugal* or *efferent* nerves, or *nerves of motion.* This peculiarity cannot be accounted for from any special variety of structure which the nerves possess, or the tissues to which they are distributed. The two kinds of nerves lie side by side in the same sheath. Those which have no peripheral termination are called *intercentral*, as those at the back part of the optic commissure. The nervous force (vis nervosa) by which secretion, nutrition, etc., are influenced, seems to be conveyed along both sensitive and motor nerves.

Fig 104.

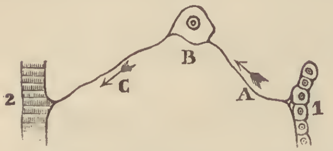


Diagram of reflex action; 1, surface (epithelium); 2, muscle; A, nerve of sensation; B, central nerve cell; C, nerve of motion; A, B, C, form the *nerve arc* which presides over reflex action.

Nerve fibres require to be stimulated, in order to manifest their peculiar endowments, since they do not possess the power of generating force in themselves, or of originating impulses to action. The property of conducting impressions is called *excitability;* but this is never manifested until some stimulus is applied. The stimuli by which the action of nerves is ordinarily provoked, are of *two* kinds, *mental* and *physical*; the former relates to the will, the latter to the influence of external objects, and chemical, mechanical and electric actions or irritations. These stimuli when applied to parts endowed with sensation, or to sensitive nerves, produce sensations, and when applied to the nerves of muscles produce contractions. Nerves, though divided, when irritated or stimulated have, by virtue of their excitability, the power of exciting contractions in the muscles to which they are distributed; but when the continuity of the nervous matter is broken, or the fibre bruised, or seriously injured, the property of propagating nervous force is destroyed. Nervous action is also excited by temperature; for example, any very hot substance applied to the body produces muscular contraction, and a sensation of pain is transmitted to the nervous centre; the

application of a very cold substance has a somewhat similar effect. Chemical stimuli excite the action of both sensitive and motor nerves, when their effect is not so strong as to destroy the structure of the nerve to which they are applied. A similar manifestation of nervous power is produced by electricity. Nerve force travels along the fibres with immense rapidity; its velocity has been ascertained by Helmholtz and others at 111 feet per second in motor, and 140 in sensory nerves.

LAWS OF ACTION IN NERVE FIBRES.—All nerve fibres are mere conductors of impressions. An impression made on any fibre is transmitted along it without interruption, and without being imparted to any of the fibres lying near it. This is probably due to the fact, that the contents of each fibre are isolated from those of adjacent fibres, by the membrane or sheath in which it is enclosed. It is also supposed that the white substance of Schwann acts as an insulator. No nerve fibre can convey more than one kind of impression; for example, the motor nerve conveys only motor impulse; the sensitive nerve transmits only sensation when propagated to the brain, and the nerves of special sense, as the optic and auditory, convey only sensations of light and sound. *Nerves of sensation* are able to convey impressions only from the parts to which they are distributed, towards the nervous centre with which they communicate; for example, when a sensitive nerve is divided, and irritation is applied to that portion still connected with the nervous centre, sensation is perceived, or a reflex action ensues; but when the distal portion is irritated no effect is produced. When the trunk of a nerve is irritated, the sensation is felt in all the parts which receive branches from it; for example, if the ulnar nerve be compressed behind the internal condyle of the humerus, a peculiar tingling sensation is felt in the little finger, and in the ulnar half of the ring finger. Even when part of a limb has been amputated, any pressure or irritation to the remaining portions of the

nerves which ramified in it, gives rise to sensations which the mind refers to the lost part, as well as to the stump, and tinglings and pains are complained of in the lost finger, toe, hand or foot, as the case may be. Again, when the relative position of the peripheral extremities of sensitive nerves is changed artificially, as in the restoration of the nose from the integument of the forehead, the sensation produced when the new nose thus formed, while connected by its isthmus, is touched, is referred to the forehead. This peculiarity may be exemplified by the following experiment:—Cross the middle finger of the hand behind the index finger so that the extremity is on the radial side of the latter, then roll the two fingers over a pea or marble, and a sensation will be produced which leads the mind to suppose the existence of two distinct bodies. This is owing to the impression being made at the same time on the sides of the fingers most removed from each other in the natural position. Generally, however, the mind discerns the exact part of a nerve fibre that is irritated, and even when, as is the case in the retina, two or more impressions are made at the same instant on different parts of the same fibre, the mind can discriminate and perceive each, and compare the one with the other.

Several of the *laws of action* in *motor nerves* are similar to the foregoing. For example, motor influence is transmitted only in the direction of the fibres going to the muscles, and irritation of a motor nerve excites contraction in all the muscles supplied by the branches given off below the point of irritation; but those supplied by branches given off above this point are never directly affected. Again, since motor nerves are isolated as completely as sensitive, the irritation of a part of the fibres of a motor nerve does not affect the motor power of the whole trunk, but only that of the portion to which the stimulus is applied.

Development of Nerve Tissue.—*Nerve fibres* appear to be formed in the same manner as muscles. The primitive cells are imbedded in protoplasm or intercellular substance

which is arranged in the shape and form of the developing nerve fibre. The cells elongate, the nuclei increase in number, and the protoplasm and cell contents become transformed into the different parts of the nerve fibre— viz, the sheath, white substance of Schwann, and axis cylinder or "band of Remak." In the nerve centres the cells remain in their primitive state, the only change being that they increase in size, and develope in their interior some pigmentary granules.

In the *process of regeneration*, after incision or injury, the extremities of the nerves are united at first by fibrous tissue, which after a time is replaced by nerve tissue, if the cut extremities are not too far removed. Perfect restoration of the action of the nerve, however, does not generally take place, owing probably to the want of exact coaptation between the cerebral and peripheral portions of the same fasciculi ; for example, the cerebral portion of a motor filament may unite with the peripheral portion of a sensitive one, and the action of each will be partially neutralized.

VASCULAR SUPPLY.—The blood-vessels supplying a nerve terminate in a minute capillary plexus, disposed similarly to those of muscles, running parallel to the nerve fibres. They are connected together by short transverse branches, forming narrow oblong meshes.

FUNCTION OF THE NERVOUS CENTRES.—The nervous centres embrace all those parts of the nervous system which contain nerve corpuscles, as the brain, spinal cord, and the ganglia of the cerebro-spinal and sympathetic system. Their function is that of variously disposing and transferring the impressions received through their several sensitive nerves. Nerve fibres, as already stated, are simply *conductors* of nervous influence. Nervous centres are not only *conductors*, but also *communicators* and *reflectors* of nervous impressions. The brain *conducts, communicates, reflects,* and *perceives* or takes cognizance of impressions.

CONDUCTION.—When an impression is produced on the periphery of a nerve, as, *e. g.*, in the mucous membrane of the intestines by the presence of a portion of food, it is *conducted* to the adjacent ganglia of the sympathetic, from which a motor impulse returns to the intestines and produces a movement of the muscular coat. If, however, any irritant substance, as a drastic cathartic, be mixed with the food, a stronger impression is produced, and this is conducted through the nearest ganglia to others more remote, and from all these, motor impulses proceed which excite a more forcible and widely extended action of the small intestine; or the impression may be conducted through the ganglia of the spinal cord, from which motor impulses may proceed to the abdominal and other muscles, producing cramp. Besides, the same morbid impression may be conducted through the spinal cord to the cerebrum, where the mind can perceive and take cognizance of it.

COMMUNICATION.—Impressions made on the nervous centres may be *communicated* from the fibres that brought them to others, and in this communication they may be either *transferred* or *diffused.* The *transference* of impressions may be seen in disease of the hip joint. The impression made by the disease on the nerves of the hip is conveyed to the spinal cord; it is thence transferred to the central termination of the nerve fibres of the knee joint; through these the impression is conducted to the brain, and the mind, referring the sensation to the part from which it is accustomed, through these nerves, to receive impressions, feels as if the pain were in the knee. In the same way, when the sun's rays fall strongly on the retina, a tickling may be felt in the nose, causing sneezing; or irritation in any part of the respiratory organs gives rise to a sensation of tickling in the glottis, and produces coughing. When an impression received at a nervous centre is transferred to many other fibres in the same centre, it is said to be *diffused,* the sensation extending far beyond the part from

which the primary impression proceeded, as is seen in toothache, in which the adjoining teeth and surrounding parts are similarly affected. The pain caused by the presence of a calculus in the ureter or bladder, is diffused far and wide.

Reflection or Reflex Action.—The reflection of impressions exhibits an important function common to all nervous centres, and is the source of all reflex movements. The preceding examples are all instances of reflection, or *reflex action*, for the manifestation of which three conditions are necessary. *First*, sensitive nerve fibres, to convey an impression. *Secondly*, a nervous centre, to which the impression may be conveyed, and in which it may be reflected. *Thirdly*, motor nerve fibres, upon which this impression may be conducted to the contracting tissue (Fig. 104). If any of these conditions be absent, a proper reflex action cannot take place. They are all involuntary, and in health they have a distinct purpose to subserve in the animal economy, as in the movements of the intestines, the respiratory organs, contraction of the pupils, closure of the glottis, etc.; but in disease many of them are irregular and purposeless, as in chorea, convulsions, etc. Reflex actions may be divided into *primary*, and *secondary* or *acquired*. As instances of the former, may be mentioned sucking in infants, contraction of the pupil, etc.; and of the latter, walking, reading, and writing.

Nerve Force (*vis nervosa*).—The special endowment by which nerves act and manifest their vitality is a peculiar one inherent in the structure and constitution of the nervous substance. It manifests itself in its effects on the muscles, in sensation, secretion, excretion, nutrition, etc. Nervous force, though not identical, presents many points of resemblance to Voltaic electricity. For the production of the latter, the ordinary requisites are two dissimilar metals, as zinc and platinum or copper, and an interposed compound fluid, as dilute sulphuric acid. When these metals are placed in contact with each other, chemical action com-

mences, a current sets in a definite direction, and a state of *polarity* or *electrical tension* is produced. The production of nervous force, or nervous polarity, may have as analogues two kinds of nervous matter, cells and fibres, and the presence of a fluid.

From the structure and peculiarity of the nervous centres, there is much to justify the opinion that each nerve vesicle, and fibre connected with it, together with the blood-vessels and fluid surrounding them, is a distinct apparatus for the development of *nervous polarity.* The whole nervous system is therefore in a constant state of nervous polarity, and is prepared at any moment to receive, conduct, or communicate impressions, or convey motor impulses. A slight mechanical or chemical stimulus to a nerve, is capable of producing in it a state of polarity, and rendering it capable of conducting impressions or motor impulse; *e.g.*, pain is excited by touching a sensitive nerve, and contractions may be produced by irritating the motor nerve of an amputated limb.

THE SPINAL CORD.

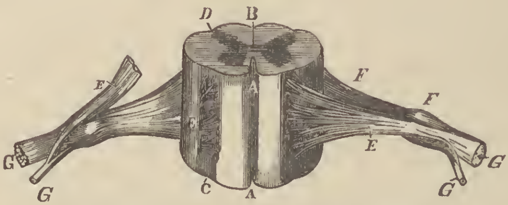
The spinal cord is a cylindrical column of nerve substance, connected above with the brain, through the medulla oblongata, and terminating below—opposite the first or second lumbar vertebra—in a slender filament of grey substance, the *filum terminale,* which lies among the leash of nerves forming the *cauda equina.* It presents two enlargements, one in the cervical region, extending from the third cervical to the first dorsal vertebra, and the other in the lumbar, opposite the last dorsal or first lumbar. The spinal cord consists of two symmetrical halves, united in the middle line by a commissure. They are separated in front and behind by a vertical *fissure,* the *posterior fissure* being deeper, but narrower than the *anterior.* On each side of the anterior fissure, a linear series of foramina may be seen, from which emerge the anterior roots of the spinal nerves; this is the

so-called *anterior lateral fissure* of the cord. On each side, near the posterior part of the cord, and corresponding with the posterior roots of the spinal nerves, may be seen a delicate fissure, the *posterior lateral fissure.* On each side, and near the posterior fissure, is a slight longitudinal furrow—the *posterior medio-lateral fissure.* These fissures divide each half of the cord into four *columns, anterior, lateral, posterior* and *posterior median* columns. The *anterior column* is situated between the anterior median and the anterior lateral fissures. It is continuous with the anterior pyramid of the medulla oblongata, in which decussation of the anterior columns takes place. The *lateral column* is situated between the anterior lateral and posterior lateral fissures, and is continuous above with the lateral tract of the medulla. The *posterior column* is situated between the posterior lateral and the posterior medio-lateral fissures, and is continuous with the restiform body of the medulla. The *posterior median column* is a narrow segment situated between the posterior medio-lateral and the posterior median fissures, and is continuous above with the posterior pyramid of the medulla oblongata.

STRUCTURE OF THE CORD.—The cord consists of fibrous and vesicular, or white and grey nervous substance; the former is more extensive, and situated externally; the latter occupies the centre, and consists of two crescentic masses, connected together by a transverse band, the gray commissure. In the centre of this commissure, and extending the whole length of the cord, is a minute canal lined by columnar ciliated epithelium, which communicates above with the fourth ventricle. Both in front of and behind the gray commissure is a transverse band of white substance, the anterior and posterior white commissures; these connect the white substance of each lateral half of the cord, and form the floor of the anterior and posterior median fissures respectively. Each crescentic mass of gray matter presents an anterior and a posterior horn; the former is short and

thick, and does not quite reach the anterior lateral fissure; the latter is long and slender, and extends to the posterior lateral fissure. The anterior roots of the spinal nerves are connected with the anterior horn, and the posterior roots with the posterior horn. The white substance of the cord

Fig. 105.



A, the anterior median fissure; B, posterior median fissure; C, anterior lateral depression, over which the anterior nerve-roots are seen to spread; D, posterior lateral groove, into which the posterior roots are seen to sink; E, anterior roots passing the ganglion; E, the anterior root divided; F, the posterior roots, the fibres of which pass into the ganglion; G, the united or compound nerve, and its division into anterior and posterior branches.

consists of transverse, oblique, and longitudinal nerve fibres, blood-vessels and areolar tissue; and the gray substance consists of smaller nerve fibres, nerve cells, blood-vessels, and delicate areolar tissue (neuroglia). There are a number of large multipolar nerve cells in the anterior and posterior cornu, and also midway between the two cornu, near the external surface of gray matter.

Spinal Nerves.—The spinal nerves consist of thirty-one pairs, issuing from the sides of the whole length of the cord. Each nerve arises by two roots, an *anterior* or motor, and a *posterior* or sensitive. The posterior root is larger than the anterior root, (except the first), and has a ganglion developed on it (Fig. 105). Immediately beyond this ganglion the two roots coalesce, and the trunk thus formed passes through the intervertebral foramen, after which it again divides into two branches, an anterior, which supplies the anterior surface of the body and the extremities, and a posterior, which supplies the posterior part of the body, each branch containing fibres from both roots. The anterior roots arise from the antero-lateral columns, and are also

connected with the anterior horn of the gray substance, and the multipolar cells found connected with it; and the posterior roots arise from the posterior part of the lateral column and the posterior horns of the gray substance; the former consist exclusively of motor fibres, and the latter exclusively of sensitive fibres.

Function of the Spinal Cord.—The spinal cord transmits impressions from the periphery to the brain, and also enables the latter to bring into action the motor nerves. Division of, or injury to the spinal cord, causes an interruption of voluntary motion and sensation in those parts supplied by nerves below the part affected, while the functions of the parts above remain unimpaired. But though the influence of the brain in receiving sensation, and exciting voluntary motion is cut off or interrupted, the portions of the cord below the affected part still possess excito-motor action, and hence the cord may be regarded as a nervous centre; for example, in cases of paralysis, muscular action may be excited by tickling the palms of the hands, or soles of the feet with a feather. It has been shown, by experiment, that irritation to the anterior columns of the cord is followed by convulsive movements of all the parts supplied with motor nerves below the irritated part, but no signs of pain are manifested; while irritation of the posterior columns appears to cause excruciating pain, without producing any muscular movement besides such as may be produced by the will or reflection. Again, when the spinal cord is completely severed, irritation of the posterior columns of the severed part produces no effect; but irritation of the anterior columns is followed by violent movements. On the other hand, irritation of the posterior columns of the portion of the cord connected with the brain causes acute pain and reflex movements; while irritation of the anterior columns of the same produces no effect. Again, when both anterior columns alone are divided, the power of voluntary motion is lost in parts below, the sensibility remaining per-

fect; and when both posterior columns are divided, sensation is lost in the parts below, the power of motion remaining unimpaired. From this it would appear that the anterior columns are motor, and the posterior sensitive; nevertheless, the result of injuries, and disease of different parts of the cord, are not always in accordance with, but in some instances directly contrary to it; for example, cases have been seen in which complete loss of motion occurred without any impairment of sensation, as the result of lesion of the posterior columns of the cord, the anterior being wholly intact. Injuries to the posterior columns are invariably attended with *hyperæsthesia* (Brown-Sequard).

The spinal cord has a *crossed action* for both motion and sensation; for example, in cerebral apoplexy the paralysis and loss of sensation are always on the side opposite to that on which the lesion has taken place. The decussation of the fibres of motion occurs between the anterior pyramids of the medulla oblongata and the opposite lateral columns of the cord and may be seen with the naked eye, (Fig. 105). The discovery of the crossed action for sensation is due to Brown Sequard. His experiments show that a decussation of sensitive impressions takes place between the posterior columns throughout the whole extent of the cord. The sensitive impressions reaching the cord, ascend for a short distance, and ultimately pass across to the opposite side of the spinal cord to reach the brain, so that if the posterior column of one side be impaired, sensation is lost on the opposite side of the body.

The spinal cord, as a nerve centre, or aggregate of many nervous centres, has the power of *conducting* and *communicating* or *transferring* impressions received, and of exhibiting *reflex action.* The two former have been already referred to in a general way. Impressions are conducted through the *gray* matter of the cord, there being in all probability, separate parts for conducting *motor* and *sensory* impressions. The spinal cord does not posess any power of

automatic or independent action, like the higher nerve centres.

The *reflex function* of the spinal cord is essentially similar to that of all the other nervous centres, and may or may not be under the control of the will. In health the will can, in a great degree, control and prevent the development of reflex actions in the extremities. If one of the legs be paralyzed, as in hemiplegia from disease of the brain, and a stimulus be applied to the sole of the foot in the paralyzed limb, reflex actions are readily produced ; but on applying the same stimulus to the sound limb, no such movements occur, the patient being able to resist the tendency to action which it produces. In cases of paraplegia from disease of the spinal cord, even where the loss of motion and sensation is complete, patients are sometimes tormented with involuntary movements of the lower extremities at night, which not only prevent sleep, but also occasion pain and distress. It is no doubt caused by irritation at the seat of the lesion.

The reflex action of the spinal cord is essentially involuntary ; for example, the respiratory movements are performed while the mind is occupied, or during sleep or anæsthesia ; yet, the mind can by a voluntary act direct and strengthen them, and adapt them to the several acts of speech, effort, etc. Some reflex actions may be controlled, or entirely prevented by the will, which thus exercises an *inhibitory* action over them ; for example, when the sole of the foot is tickled we can by an act of the will control the reflex action which it occasions. When the limb is pinched or pricked, it is involuntarily withdrawn from the instrument of injury, and the eye is involuntarily closed when a blow on the face is threatened; but both these reflex actions may be controlled by an effort of the will. Many reflex actions are entirely involuntary as for example, the contraction of the pupil, the movements of the intestines (except defecation), the action of the uterus in parturition, etc.

The spinal cord, with its encephalic prolongation, may be said to supply, by its reflex power, the conditions requisite for the maintenance of the various muscular movements which are essential to the continuance of the organic processes; and, as Marshall Hall has pointed out, it especially governs the various orifices of ingress and egress. Thus, the act of deglutition is entirely dependent on the spinal axis (medulla), and the nerves proceeding from it. The action of the cardiac and pyloric orifices of the stomach is wholly regulated without the consent of the will. The movements of the intestines are influenced by the spinal cord through the sympathetic system. The sphincter ani and sphincter vesicæ are under its influence, although partly subject to the control of the will. The reflex action of the spinal cord is also exhibited in the expulsion of the generative products as the semen, in defecation, micturition, and in parturition in its second stage.

The phenomena of spinal reflex action in man are more marked in disease than in health; *e. g*., in tetanus a slight touch on the skin, or a breath of air, is sufficient to throw the whole body into convulsions; a similar state is induced by the introduction of strychnine or opium in frogs. In these instances, the spinal cord is in a state of polar excitement, and is kept so by the constant irritation propagated to it by the wounded part, on the one hand, or the poisonous substance circulating in the blood, on the other, there being no inflammatory or congested condition either of the cord or its membranes.

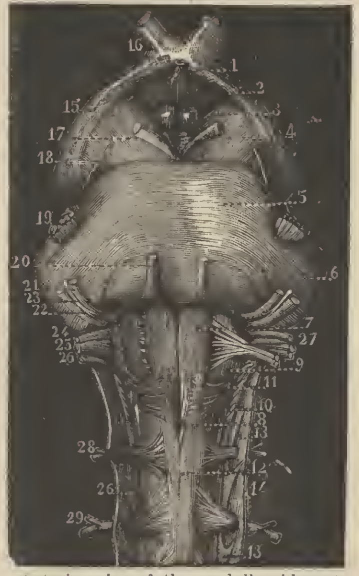
The spinal cord is constantly in activity; in all periods and phases of life, the movements which are essential to its continued maintenance are kept up without sensible effort. "The spinal system never sleeps;" it is the brain alone which is torpid during sleep, and whose functions are affected by this torpidity. It has, however, its periods of momentary rest, similar to other organs of the body, as the heart, lungs, etc., which appear to be constantly in action.

ENCEPHALON.

The encephalon is situated in the cranial cavity, and consists of the *medulla oblongata, pons Varolii, cerebellum* and *cerebrum.*

Medulla Oblongata.—The medulla oblongata is the cephalic prolongation of the spinal cord, and connects it with the brain. It is larger than the spinal cord, and is divided into segments, which are continuous with the columns of the spinal cord below. It is separated into two lateral halves by fissures, which correspond with the anterior and posterior fissures of the cord; and each lateral half is again subdivided by minor grooves into four columns, the *anterior pyramid, lateral tract and olivary body, restiform body* and *posterior pyramid.* These are continuous with the anterior, lateral, posterior, and posterior median columns of the spinal cord respectively.

Fig. 106.



Anterior view of the medulla oblongata and pons Varolii. 1. infundibulum; 2, tuber cinereum; 3, corpora albicantia; 4, cerebral peduncle; 5, pons Varolii; 6, origin of the middle peduncle of the cerebellum; 7, *anterior pyramids of the medulla oblongata;* 8, *decussation of the anterior pyramids;* 9, *olivary bodies;* 10, *restiform bodies;* 11, *arciform fibres;* 12, upper extremity of the spinal cord; 13, ligamentum denticulatum; 14, dura mater of the cord; 15, optic tracts; 16, optic commissure or chiasm; 17, motor oculi; 18, pathetic; 19, fifth nerve; 20, abducens; 21, facial; 22, auditory; (23, nerve of Wrisberg); 24, glosso-pharyngeal; 25, pneumogastric; 26, 26, spinal accessory; 27, hypoglossal; 28, 29, cervical nerves. (Sappey).

Structure.—The *anterior pyramid* is composed entirely of white fibres derived from the anterior column of the cord of its own side, and from the lateral columns of the opposite half of the cord, and is continued upwards into the cerebrum and cerebellum. The cerebellar fibres pass beneath the olivary body, join the restiform body and

spread out in the cerebellum; some of the cerebral fibres inclose the olivary body and enter the pons as the olivary fasciculus, but the mass of the fibres enter the pons Varolii in their passage upwards to the cerebrum. The decussation between the anterior pyramids may be distinctly seen with the naked eye.

The *lateral tract* is continuous with the lateral column of the cord. Its fibres pass in three different directions; the external join the restiform body, and pass to the cerebellum; the internal pass forwards, pushing aside the fibres of the anterior column, and form part of the opposite anterior pyramid, and the middle fibres ascend to the cerebrum, forming the *fasciculi teretes* in the floor of the fourth ventricle. The *olivary body* presents on a transverse section, a whitish substance externally, and a grayish-colored body in the interior—the *corpus dentatum*—which presents a zigzag outline, and contains some white substance in the interior, which communicates with that on the external surface by means of an aperture in its posterior part.

The *restiform body* is continuous below with the posterior column of the cord, and receives some fibres from the lateral and anterior columns; superiorly, it *divides* into two fasciculi; the external one enters the cerebellum; the internal one joins the posterior pyramid, and blends with the fasciculi teretes as it passes up to the cerebrum.

The *posterior pyramids* are continuous with the posterior median columns of the cord. Opposite the apex of the floor of the fourth ventricle, they present an enlargement (*process clavatus*), and diverging, form the lateral boundaries of the *calamus scriptorius*. They then join the external fasciculus of the restiform bodies, and pass with them up to the cerebrum.

In the lower part of the medulla the gray matter is arranged as in the cord; but in the upper part it becomes more abundant, and is disposed apparently with less regularity.

FUNCTION OF THE MEDULLA OBLONGATA.—The general function of the medulla oblongata is similar to that of the spinal cord. It may be regarded as a conductor of impressions, in which respect it has a wider extent of function than any other part of the nervous system, since all impressions between the brain and spinal cord pass through it. In consequence of the decussation of the anterior pyramids, motor impressions proceeding from the brain pass across to the opposite side of the spinal cord; for example, in injury to one side of the head, producing paralysis, the loss of motion is always on the side opposite to that on which the injury was received.

Besides the function of conduction, the medulla oblongata, acting as a nervous centre, presides over the functions of *respiration*, *deglutition*, etc. The brain of the lower animals may be wholly removed above, and yet life may continue, and the respiratory function be carried on. The same is the case when the spinal cord below the phrenic nerve is removed; and even when both the brain and spinal cord are removed, the function of respiration may be continued; but whenever the medulla is wounded the function is instantly arrested, and the animal dies as if asphyxiated. The medulla oblongata may continue to discharge its functions as a nervous centre after the power of conduction has ceased to act; thus, in coma from apoplexy or compression, and in anæsthesia from ether or chloroform, patients continue to breathe, although they are wholly insensible. The reflex action of the medulla is peculiar from having a very wide range of connection. The principal centripetal nerves engaged in respiration are the pneumogastrics; but that these are not the only ones may be shown by their division when respiration becomes slower, but is not arrested. The wide range of connection which belongs to the medulla is further shown by the fact that impressions on the surface of the body may induce respiratory movements, as *e.g.*, dashing

cold water on the face or body is instantly followed by a deep inspiration.

From the medulla arise the movements required in the act of deglutition. This may be shown by the persistence of the power of deglutition after the removal of the cerebrum and cerebellum, and by its complete arrest when the medulla is injured. The reflex power of the medulla in deglutition is much simpler and more restricted than in respiration. It is also the *centre* for the movements required in speech and mastication; for the special senses of hearing and taste; for regulating the action of the heart (p. 212); the action of the iris and ciliary muscle; and the secretion of the saliva. It is likewise the chief *vaso-motor* centre from which fibres pass down the cord, accompanying the spinal and sympathetic nerves, and are distributed to the blood-vessels (p. 219.) The gray matter in the floor of the fourth ventricle when irritated produces glycosuria, and is therefore called the *diabetic* centre (p. 151.) This is probably the result merely of stimulating the vaso-motor centre.

PONS VAROLII.—The pons Varolii, meso-cephalon or tuber annulare, is the bond of union between the cerebrum, cerebellum, and medulla oblongata. In structure it consists of *longitudinal* and *transverse* fibres, intermixed with gray matter. The *longitudinal* fibres are continued up through the pons from the anterior pyramids, olivary bodies, lateral and posterior columns of the cord. The *transverse* fibres connect the two hemispheres of the cerebellum, forming the transverse commissure, and are divided into a *superficial* and *deep* layer; the former passes across the surface of the pons, and the latter, situated deeply, decussates with the longitudinal fibres.

FUNCTION OF THE PONS.—It acts as a conductor and also as a nerve centre. As a conductor it is the channel through which impressions are conveyed from the spinal cord to the cerebrum and cerebellum, and also between the two hemispheres of the cerebellum. It is the nervous centre for *stasis*

and *progression,* and may also be regarded as the connecting link between the different portions of the encephalon, for when the cerebrum and cerebellum are removed in one of the lower animals, it may still have sensation of painful impressions and power of motion, (*Vulpian.*) It is a nervous centre for higher and more definite reflex actions than the medulla or any part of the spinal cord—reflex actions of an emotional and instinctive character.

In hemiplegia from disease of the corpus striatum, there is paralysis on the opposite side of the body, and paralysis of the face on the same side as that of the body (cognate). This shows that the cranial nerves have a crossed action as well as the spinal nerves. Unilateral disease of the pons Varolii is liable to involve the facial nerve, before decussation has taken place, and the paralysis of the face will then be on the opposite side to that of the body (alternate). Hence in lesions of the brain above or in front of the pons, there is *cognate paralysis,* and in lesions of the pons, *alternate paralysis.*

CEREBELLUM.—The cerebellum consists of two lateral hemispheres connected together by a transverse commissure or band, the vermiform process. It is situated in the posterior fossa of the cranium, beneath the posterior lobes of the cerebrum, from which it is separated by the tentorium cerebelli. It is oblong in shape, measuring from three and a half to four inches transversely; from two to two and a half from before backwards, and two inches in thickness, and weighs from five to six ounces. Each hemisphere is divided into several lobes, of different sizes, and its surface is marked by numerous curved furrows or sulci, which vary in depth in different parts. Its surface is covered by the pia mater.

STRUCTURE.—It consists of gray and white matter; the former, darker than that of the cerebrum, occupies the surface; the latter the interior. When divided vertically it is seen to consist of a central stem of white matter, which con-

tains in its interior a grayish mass—the corpus dentatum. The central stem of white matter sends forth laminæ towards the surface, which are surrounded by the gray matter so that the cut surface of the organ presents a foliated appearance to which the name *arbor vitæ* has been given. A vertical section of the gray matter or cortical substance presents the following appearance. Externally is a thick layer of fine connective tissue in which is seen a number of spherical corpuscles like those of the granular layer of the retina; next is a single layer of branched nerve cells (*cells of Purkinje*) the branches of which pass upwards into the external layer and blend with the corpuscles, and some single branches downwards. Beneath this is the so-called granular layer which consists of a dense layer of rounded corpuscles, resembling the nuclear layer of the retina ; and lastly a layer of nerve fibres with a few scattered corpuscles ; this layer partly belongs to the white substance.

Fig. 107.

Vertical section of dog's cerebellum ; pm, pia mater ; p, corpuscles of Purkinje ; g, layer of ganglionic corpuscles ; f, layer of nerve fibres with a few scattered corpuscles.

The cerebellum is connected with the rest of the encephalon by processes or prolongations, called peduncles. These are three in number, the *superior, middle* and *inferior*. The *superior peduncles* connect the cerebellum with the cerebrum. They pass upwards beneath the testes to the crura cerebri and optic thalami, each peduncle forming part of the lateral boundary of the fourth ventricle. Beneath the corpora quadrigemina the innermost fibres of each peduncle decussate with each other, some fibres from one side of the cerebellum communicating with the opposite side of the cerebrum. The *middle peduncles*, the largest of the three, connect together the two hemispheres of the cerebellum, and form the transverse fibres of the pons Varolii.

The *inferior peduncles* (crura cerebelli) connect the cerebellum with the medulla oblongata. They pass downwards to the back part of the medulla, and form part of the restiform bodies.

FUNCTION OF THE CEREBELLUM.—The cerebellum is insensible to irritation, and may be cut away without causing pain; but if any of the crura be touched, pain is instantly felt. Its removal is not attended with any loss or disorder of sensibility; the animal can see, hear, smell, etc., as before its removal; but he has lost the power of springing, flying, walking, standing, etc., and his actions are like those of a drunken man. The action of its two halves must always be balanced, for if one-half of the cerebellum be removed, or one of its crura divided, the animal exhibits a tendency to roll over upon its longitudinal axis, and from the side injured. From the above circumstances it would appear, that the function of the cerebellum is to *regulate and co-ordinate the muscular movements* of the body. The influence of each half of the cerebellum is directed to muscles on the opposite side of the body. It is also the organ through which the mind acquires a knowledge of the state and position of the muscles, and exerts a will upon them—the organ of muscular sense.

The cerebellum is supposed by some to be the organ of sexual instinct, or of amativeness. The facts adduced in favor of it are—1st, cases in which atrophy of the testes and loss of sexual passion have resulted from injuries to the cerebellum; 2nd, disease of the cerebellum has been attended with almost constant erection of the penis, and frequent seminal emissions; 3rd, that it has seemed possible to estimate the degree of sexual passion in different animals by the comparative size of the cerebellum. In reference to the first class of facts, the loss of sexual passion may have been the consequence of atrophy of the testes, and hence these facts have little bearing on the question, unless it can be shown that the loss of sexual passion followed the injury of

the cerebellum, before the testes began to diminish. Disease of the cerebellum proves nothing, because the same thing more generally occurs in disease of the medulla and spinal cord. On the other hand, cases are recorded in which the whole of the cerebellum has been disorganized, or completely absent, without loss of the sexual passion. Besides, among animals there is no proportion between the size of the cerebellum and the development of the sexual passion, and castration in early life is not followed by any diminution of this organ. The cerebellum of the cock is no larger than that of the hen, although the sexual passion is many times greater. The cerebellum in frogs and toads is only a small bar of nerve substance, yet the sexual instinct is very strong.

THE CEREBRUM.—The cerebrum occupies the upper part of the cranial cavity, resting upon the anterior and middle fossæ of the base of the skull, and is separated posteriorly from the cerebellum by the tentorium cerebelli. It is ovoidal in shape, and is divided into two lateral hemispheres, which are connected together by a broad transverse commissure of white matter—the *corpus callosum*. The average weight of the brain is about fifty ounces in the male, and forty-five in the female. The weight of the brain increases rapidly up to the seventh year, more slowly up to twenty, and still more slowly up to the fortieth year. When it reaches the maximum, it remains stationary for a few years, and then declines as age advances about one ounce for each subsequent decennial period. As a rule, the size of the brain bears a general relation to the intellectual capacity of the individual. The brain of Cuvier weighed rather more than sixty-four ounces; Dr. Abercrombie sixty-three; Ruloff, a celebrated linguist, executed for murder in 1879, fifty-nine; James Fisk, Jr., fifty-eight; Spurzheim fifty-five; Daniel Webster, fifty-three; Agassiz, fifty-three; Dupuytren, forty-nine (Cruveilhier). The brain of the Hon. D'Arcy McGee, the celebrated Canadian statesman, weighed fifty-

nine ounces. Cromwell's brain was said to have weighed eighty-two ounces, and Byron's seventy-nine; but these figures are not generally accepted by physiologists. On the other hand, the brain of an idiot seldom weighs more than twenty-three ounces. Wagner, however, mentions a case of an idiot whose brain weighed fifty-four ounces, and Dr. Tuke reports a case in which the brain of a congenital epileptic idiot weighed sixty ounces, but these are exceptional. In only two animals is the brain larger than in man, viz., the elephant and the whale.

The *mere* comparative size of the brain, or *quantity*, however, does not always give an accurate measure of the amount of mental power, for not unfrequently men possessing large and well-formed heads are seen, whose mental capabilities are not greater than those of others whose crania have the same general proportion, but are much smaller. Large brains, with deficient activity, are commonly found in persons of a lymphatic temperament; whilst small brains, and great activity, characterize the sanguine and nervous temperaments. The *quality* of the nerve tissue in regard to fineness of nerve fibres, and cells, the degree of vascularity, and the number and extent of the convolutions, bear an important relation to the intellectual capacity of the individual.

STRUCTURE.—The cerebrum consists of two kinds of nerve tissue, the *gray* and the *white;* the former is situated externally, the latter internally. The surface of the cerebrum presents a number of *convolutions* or foldings, separated from one another by depressions or sulci of various depths. The outer surface of each convolution is composed of gray matter, which is sometimes called the cortical substance, and the interior consists of white matter. The convolutions are admirably adapted to increase the extent of surface or amount of gray matter, without occupying much additional space. The gray matter of the convolutions, when closely examined, however, appears to consist of from

four to six layers of gray and white tissue placed alternately, from two to three layers of gray substance, and an equal number of white; the latter occupying the surface. A vertical section of these layers presents the appearance represented in the accompanying figure: 1st, horizontal transverse and oblique nerve fibres; 2nd, a layer of fibres with a few nerve cells; 3rd, a layer with numerous cells of different shapes; 4th, a layer consisting of pyramidal cells, with their bases downwards, characteristic of the cerebrum; they receive two processes at their inferior extremity, and give off one upwards, and are interspersed among radiating nerve fibres; 5th, a narrow layer with irregular cells like those of the cerebellum; 6th, a broad layer with irregular and fusiform cells. The *sulci* are generally about an inch in depth; but they vary in different brains, and in different parts of the same brain, being usually deepest on the outer surface of the hemispheres. The convolutions of the brain are the centre of intellectual action, and their number and extent and the depth of the sulci, bear a close relation to the intellectual power of the individual. They are entirely absent in some of the lower orders of mammalia, and increase in number and extent as we ascend the scale. The largest and most constant convolutions of the human brain are the convolutions of the corpus callosum, supra-orbital convolutions, and the convolutions of the longitudinal fissure.

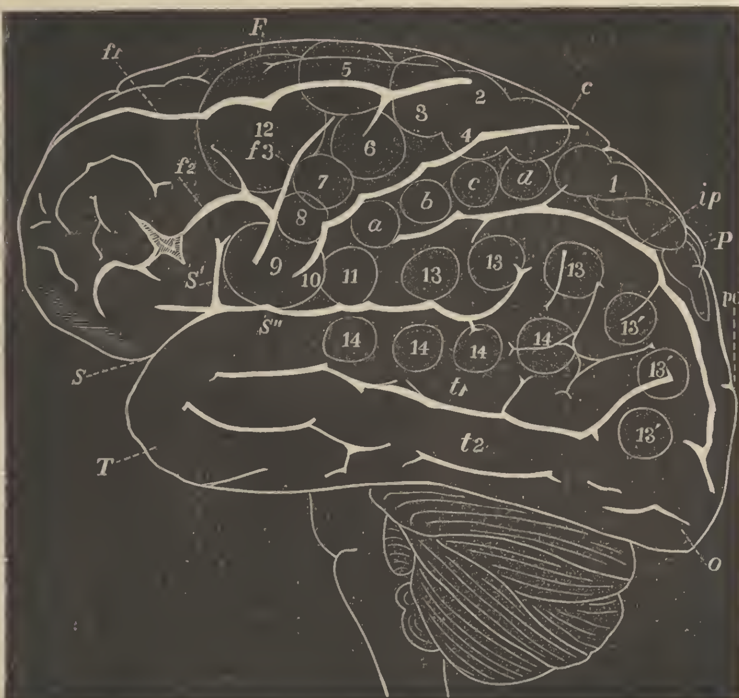
Fig. 108.

Vertical section of the cortical substance of the cerebrum; pm, pia mater; c, capillaries; nc, nerve cells in the neuroglia; pc, pyramidal cells (Schofield).

Each hemisphere is divided into five lobes: the *frontal*, (F), *parietal* (P), *temporo-sphenoidal* (T), *occipital* (O), and *central lobe*, or island of Reil, which are separated from

each other by the following fissures: the *fissure of Sylvius,* (S), *fissure of Rolando* (central fissure) (c), and *parieto-occi-*

Fig. 109.



F, frontal lobe; P, parietal lobe; O, occipital lobe; T, temporo-sphenoidal lobe; S, fissure of Sylvius; S′, horizontal, S′′, ascending ramus of the same; c, sulcus centralis (fissure of Rolando); f1, superior, f2, inferior; f3, præcentral fissure; ip, interparietal fissure; po, parieto-occipital fissure; t1, first; t2, second temporo-sphenoidal fissures (Ecker).

pital fissure (po). (Fig. 108.) The lobes are again subdivided into lobules. The frontal lobe is bounded behind by fissure of Rolando, and below by the fissure of Sylvius; the parietal lobe, in front by the fissure of Rolando, and behind by the parieto-occipital fissure, which in man appears as a notch in the inner margin of the hemisphere; the temporo-sphenoidal lobe is situated beneath the horizontal branch of the fissure of Sylvius; the occipital lobe is situated behind the parieto-occipital fissure; and the central lobe, or island of Reil, is situated upon the under surface of the

anterior part of the cerebrum at the bifurcation of the fissure of Sylvius. The under surface of the frontal lobe occupies the anterior fossa of the base of the cranium, the parietal and temporo-sphenoidal the middle fossa, and the occipital the posterior fossa. They were formerly named anterior, middle, and posterior lobes respectively.

The figures in the accompanying diagram of the human brain are made to correspond with the areas of the brain of the monkey as determined by the experiments of Ferrier, and the effects of stimulating the various areas refers to the brain of the monkey.

1 (On the superior parietal lobule). Movement of the opposite hind foot as in walking.

2, 3, 4, (The fissure of Rolando). Complex movements of the opposite leg and arm, and of the trunk, as in swimming.

a, *b*, *c*, *d*, (Postero-parietal convolution). Combined movements of the fingers and wrist of the opposite hand, closure of the fist, and prehensile movements.

5, (Superior frontal convolution). Extension forward of the opposite arm.

6, (Upper part of the antero-parietal convolution). Supination and flexion of the opposite forearm.

7, (Median portion of the same convolution). Elevation of the opposite angle of the mouth—zygomatic action.

8, (Lower down on the same convolution). Elevation of the ala nasi and upper lip, and depression of lower, on the opposite side.

9, 10, (Inferior extremity of the same convolution, Broca's convolution). Opening of the mouth with (9) protrusion and (10) retraction of the tongue. *Region of aphasia. Bilateral action.*

11, (Between (10) and postero-parietal convolution). Action of platysma.

12, (Posterior portions of superior and middle frontal convolutions). Elevation of eyelids, the pupils dilate, and the head turns toward the opposite side.

13, 13′, (Supra-marginal lobule and angular gyrus). The eyes turn to the opposite side with an upward (13) or downward (13′) deviation. The pupils generally contracted. (*Centre of vision.*)

14, (Superior temporo-sphenoidal convolution). Pricking of the opposite ear, the head turns to the opposite side, and the pupils are dilated. (*Centre of hearing.*)

Ferrier places the centres of taste and smell at the extremity of the temporo-sphenoidal lobe, and that of touch in the gyrus uncinatus and hippocampus major.

The points of difference between the brain of man and the apes, and those of all other animals, consist in the rudimentary character of the olfactory lobes, the well-defined fissure of Sylvius, the larger size of the posterior lobe completely covering the cerebellum, and the presence of posterior cornua in the lateral ventricles. The distinguishing features between the brain of man, and the ape, consist of the larger size of the brain, the greater number and complexity of the convolutions, and the blunted quadrangular contour of the frontal lobes in man; and the greater prominence of the temporo-sphenoidal lobe, the distinctness of the parieto-occipital fissure, and the upward oblique direction of the fissure of Sylvius in the ape.

The white matter of the cerebrum consists of three kinds of fibres; *diverging* or *peduncular, transverse* and *longitudinal* commissural fibres. The *diverging* or *peduncular* fibres connect the cerebrum with the medulla oblongata and spinal cord, and constitute the crura cerebri. Each crus consists of two bundles, *superficial* and *deep,* separated by a dark gray mass in the interior—the locus niger. The *superficial* fibres are continued upwards from the anterior pyramids to the cerebrum. The *deep* fibres are continued upwards from the lateral and posterior columns of the medulla and the olivary bodies. As the peduncles of the cerebrum enter the hemispheres, they diverge from one another to enclose the inter-

peduncular space, and the fibres of each pass through two large masses of gray matter, the ganglia of the brain, called the thalami optici and corpora striata, which project from the upper and inner side of each peduncle. Above these masses is situated the great transverse commissure—the corpus callosum—which connects the hemispheres together. The space bounded by the peduncles and ganglia on the sides, and the corpus callosum above, forms the general ventricular cavity. The upper part of the cavity is divided into *two lateral ventricles* by the septum lucidum, and the lower part constitutes the *third ventricle*, which communicates above with the lateral ventricles, and behind with the *fourth ventricle*, through the *iter a tertio ad quartam ventriculum.* The *fifth ventricle* is situated in the space between the two layers of the septum lucidum. The *transverse* fibres connect together the two hemispheres, forming the corpus callosum, and the anterior and posterior commissures.

The *longitudinal* fibres connect together different parts of the same hemisphere. They form the fornix, tænia semicircularis, peduncles of the pineal gland, striæ longitudinales, gyrus fornicatus, and the fasciculus uncinatus.

VASCULAR SUPPLY.—The blood-vessels of the brain are numerous and capacious, it being supplied by four large arteries, the two internal carotids and the two vertebral arteries. These vessels, in their passage, pursue a winding course to reach the brain, the object of which is to increase the extent of the surface over which the blood passes, and thus add to the amount of impediment produced by friction, in order that the supply may be more equable and uniform. These curvatures in the vessels also tend to moderate the force with which the blood may be sent to the brain under certain circumstances, as during great excitement, violent exercise, and the like. These vessels also anastomose freely with each other after entering the cranial cavity. This takes place not only between the smaller branches, but also between the primary trunks; the former

is seen all over the surface of the encephalon; the latter constitutes the well-known *circle of Willis.* This is formed in front by the anterior communicating and anterior cerebral arteries; on each side, by the trunk of the internal carotid and the posterior communicating; and behind by the posterior cerebral and point of the basilar. These vessels divide and subdivide upon the surface of the brain, until they terminate in very small arteries, which are connected together by some areolar tissue, constituting the pia mater, from which very small vessels are given off that pierce the brain substance. No large vessels pierce the cerebral substance, except at the perforated spaces; but prolongations of the pia matter, carrying with them the blood vessels, pass into the interior of the brain at the tranverse fissure, to form the velum interpositum and choroid plexuses which are situated in the ventricles.

FUNCTION OF THE CEREBRUM.—From its anatomical relation, the brain does not appear to be one of the essential or fundamental portions of the nervous system, but is a superadded organ, receiving all its impulses to action from the parts below, and acting upon the body at large through them. But its great size, its position at the summit of the cerebro-spinal system, and the vesicular substance of its convolutions affording a termination to the fibres in connection with it, mark it out as the highest in its functional relations, and as the organ through which all the processes of thought, reason, and intelligence are carried on. It is the organ of *intellectual action, emotion, ideo-motor action* and *volition,* the seat of which is the gray matter of the convolutions.

There is a very close correspondence between the relative development of the cerebrum, in the several tribes of vertebrata, and the degree of intelligence they respectively possess. In the lower animals it is difficult to say what part of their actions may be regarded as instinctive and what as intelligent. Intelligent actions are exhibited: 1st, in the

variety of means used to accomplish the same ends by different individuals, and by the same individual at different times; 2nd, in the improvement in the mode of accomplishing the object, which results from experience; 3rd, in the adaptation of means to altered circumstances. The difference between the intelligence of lower animals and pure instinct, is well seen in comparing birds with insects. Their instinctive propensities are nearly similar; but in the adaptation of their operations to peculiar circumstances, birds display a certain degree of intelligence. Certain tribes of birds, especially the parrot and its allies, are capable of being taught to perform tricks and to pronounce words, in which they exhibit simple acts of reasoning, similar to those of a child when first learning to talk. Some of the domestic animals, as the dog and the horse, manifest a considerable degree of intelligence. There is no evidence, however, that any of the lower animals have the power of directing their mental operations in obedience to the will.

With reference to the sensibility of cerebral matter, it has been ascertained by experiment that no sensation of pain is produced by irritation of the vesicular or fibrous substance. In fracture of the skull, accompanied by protrusion of the cerebral matter, it may be excised without exciting either sensation or convulsive motion. When one of the hemispheres is removed from an animal, it is followed by temporary weakness of the limbs on the opposite side of the body, and a loss of sight in the opposite eye, but the pupil remains active. When both hemispheres are removed from a pigeon, the animal remains motionless and, appears to be in a sleepy state, from which it cannot be fully aroused, but consciousness still remains, the persistence of which proves that the cerebrum is not its exclusive seat. In the frog removal of the cerebrum is attended with similar results. The animal remains motionless unless when disturbed. It sits up naturally and breathes quietly; but when pricked it jumps away, or thrown into the water it

swims. In this state a reptile or bird may survive many weeks if its physical wants be supplied. The influence of disease on the cerebrum is somewhat anomalous. In some instances extensive disease has occurred in one hemisphere, without any obvious injury to the mental powers, or interruption of the influence of the mind on the body; but morbid phenomena are invariably present when both hemispheres are affected. On the other hand a sudden lesion, although of a trifling character, may occasion very severe symptoms; for example, a slight effusion of blood in or around the substance of the corpus striatum is followed by paralysis and loss of sensation in the opposite side of the body. Although there are two hemispheres, and each appears capable of discharging in a general way the functions of both, yet the mind combines the impressions derived from both, and the ideas or impressions become single. The theory is steadily gaining ground that each faculty of the mind has a special portion of the brain appropriated to it, just as other compound organs or systems in the body, in which each has its special function. This is supported by the difference in the mental functions in different individuals, and at different periods of life; also by the phenomena of some forms of insanity. In the latter it is not often that all the faculties are disordered; some are increased while others are diminished. The phenomena of dreams, in which some of the faculties appear to be awake, while others are at rest, also support this view to some extent. In cases of hemiplegia, in which the posterior part of the third frontal convolution of the left side is diseased, it is frequently associated with *aphasia* or loss of power of expressing ideas in language. It has therefore been inferred that this portion of the brain is the *centre for language*, or rather that its healthy condition is essential to the faculty of speech. The empirical method by which Gall first fixed upon certain parts of the brain as the seat of certain faculties, is exposed to the serious fallacy that a part

on the surface of the brain may appear largely developed in consequence of the large size of some subjacent or neighboring part,—for example, a thick neck and large occipital region may indicate a large pons and medulla more frequently than a large cerebellum. Again, with respect to the cranium itself, large prominences just above the eyebrows may indicate large frontal sinuses rather than a large development of "certain organs" on the anterior lobes of the cerebrum. Gall divided the whole cerebrum into twenty-seven different organs to represent different faculties, and Spurzheim divided it into thirty-five. In some diseases, as for example, in typoid fever, the mind is more or less obtunded, and unable to combine the impressions received through both hemispheres, and the patient fancies himself as two individuals. He also sometimes holds converse with the *alter ego* he fancies is lying alongside of him and constitutes a part of himself, or requests some attention to be given to the person beside him, when in reality the attentions are required for himself.

The capacity for performing mental acts is known as the *intellect*, or reasoning power; and the capacities for those various forms of intellectual activity which pertain to the mind are called the *intellectual faculties*. These are *perception*, *imagination*, *memory* and *judgment*. When impressions are made upon some part of the body that is supplied with afferent nerves, they are transmitted through them to the sensorium, and occasion affections of the consciousness, which are called *sensations*. Every impression which affects the consciousness produces some change in the nervous centre, by which that impression is perpetuated in such a manner as to permit of its being again called up before the mind at any future time. The nature of the change by which sensory impressions are thus *registered* is not understood, and probably never will be. The acuteness with which particular sensations are felt, depends on the degree of attention they receive from the mind; for

example, ordinary impressions are not felt during sleep, or when the mind is engaged in some deep subject of study. On the other hand, impressions which are in themselves very slight may produce painful sensations, when the mind is directed strongly towards them. They are also much modified by the influence of habit. Sensations *not attended to* become blunted by frequent repetition; whilst sensations *attended to* become much more readily cognizable by the mind. Every student knows that the effluvia of the dissecting room becomes tolerable, after the nose has become habituated to it.

In some instances, sensations may be produced by internal causes; these are called *subjective sensations*, in contradistinction to *objective*, which are caused by a real material object. The most common cause of these subjective sensations is congestion or inflammation; *e. g.*, congestion in the nerves of common sensation gives rise to pain or uneasiness; in the retina or optic nerve, it produces "flashes of light;" and in the auditory nerve it occasions "a noise in the ears." Again, subjective sensations may be produced by sensations originating in objective impressions on other parts, as *e. g.*, a calculus in the bladder gives rise to pain in the glans penis; disease of the hip occasions pain in the knee.

The mental recognition of the cause of sensation is called *perception*. For the production of a sensation a conscious state of the mind is all that is required; but for the exercise of the perceptive power, the mind must be *directed towards* the sensation, and hence, when the mind is inactive, or engaged in study, the sensation may not be perceived or remembered. The perception of sensation gives rise to *ideas;* some of these partake of the nature of *feeling;* others relate to *knowledge*. An *idea* is a mental representation of an object which has been perceived by the mind—something grasped by the mind, and held up before it is an intelligible object of contemplation. Ideas may be com-

municated and rendered intelligible to other minds by means of visible signs, or by spoken language, in which certain combinations of sounds are used to express ideas; and the nearer the signs or sounds employed are to the natural expressions of the ideas which they represent, the more readily are they comprehended.

When ideas are associated with feelings of pain or pleasure, they give rise to *emotions*. These, unlike ideas, cannot be communicated or expressed in language to others; they are unutterable. Those emotional states of the mind which determine a great part of the conduct of individuals, are the result of the attachment of the feelings of pleasure and pain, and of other forms of emotional sensibility to certain classes of ideas. Thus, *grief* is the painful contemplation of loss, misfortune, or evils of any kind. *Joy* is the pleasurable feeling which accompanies success, good fortune, or good prospects, etc. *Fear* is a painful emotion excited by an expectation of future evil. *Hope* is the pleasurable expectation of future enjoyment. *Benevolence* is the pleasurable contemplation of doing good to others. *Malevolence* is a positive pleasure in the contemplation of the misfortunes of others, and so on. The emotions are partly under the control of the will, and partly independent of it.

The *determining power of the will* acts both upon the body and the mind; but the only sensible effect which the strongest effort of volition can produce on the bodily frame is that of contraction of the voluntary muscles. The immediate operation of the will is not upon the muscles, but upon the brain, in which it excites nerve force, which is transmitted along the nerves, and stimulates the muscular tissue to contraction. With reference to the action of the will upon the mind, it may be said that it possesses the power of recalling ideas which are present in the mind, excluding some and bringing others more prominently before it. This is effected by the power of *voluntary attention*,

which is the chief means through which the sequence of our thoughts is directed by the will. When the will is most strongly exerted, it causes the consciousness to be so completely engaged by one train of ideas that the mind is, for the time, incapable of receiving any other idea or impression, the individual being as insensible as if he were in a profound sleep. This power of concentration of the mind on the subject of study, is of very great importance and advantage in the acquirement of knowledge and the pursuit of truth, and one which is capable of cultivation to a considerable extent by habitual exercise. Sometimes the cerebral processes are carried on unconsciously, as for example, when one has tried in vain to remember some particular date, occurrence or *name,* and has given it up, and hours or days afterwards, it suddenly and unexpectedly flashes across the mind. This is called *unconscious cerebration.*

The *crura cerebri* are the principal conductors of impressions to and from the cerebrum. When one of them is divided, the animal moves round and round on a vertical axis from the injured to the sound side ; this is caused by a partial paralysis on the side opposite the injury. In each crus cerebri is found a small mass of gray substance, the *locus niger,* from which arises the third cranial nerves, so that this may be looked upon as the nervous centre for the chief movements of the eyeballs.

The *corpora quadrigemina,* including the *corpora geniculata* are the representatives of the optic lobes in birds, reptiles and fishes, and may be considered as centres of the sense of sight, since their removal or diseased condition is accompanied with blindness. Injury or disease on one side is followed by blindness of the opposite eye, and a slight rotatory motion, as after the division of the crus cerebri ; the pupil is also dilated. They are not only the centres from which the optic nerves arise in part, but also the organs through which the mind perceives the sensation of light The centres for co-ordination of the movements of the eye-

balls, and contraction of the pupil, lie in the nates or anterior tubercles of the corpora quadrigemina.

The *thalami optici* are also concerned to a certain extent in the function of vision, for part of the fibres of the optic tracts may be traced to their surfaces. In persons born blind, the optic thalami, and also the corpora quadrigemina, are found extremely small. Destruction of one of them produces effects similar to those of division of the crus cerebri; the animal remains standing, and turns continually round.

The *corpora striata* were supposed by Magendie to be the centres of motor power for *backward* movement, and that *forward* movement was excited by the cerebellum, these two powers being exactly counterbalanced, and hence division of the corpora striata caused an irresistible tendency to run forwards. This, however, has not been confirmed by other experimenters. Longet and others assert that animals remain stupid and immovable after division of the corpora striata, and it is only when irritated by pinching or pricking that they exhibit any disposition to move. Lesion of both the corpora striata and optic thalami on one side of the human brain, is attended with loss of sensation and voluntary power on the opposite side of the body and face. The corpora striata are regarded by some as motor, and the optic thalami as sensory ganglia, but this division of functions has not yet been clearly proved.

The *corpus callosum* connects together the two hemispheres of the cerebrum. It is entirely absent in birds, reptiles and fishes. Its division is followed by severe general injury. It probably enables the two sides of the brain to act in harmony in the performance of its highest functions.

THE MIND AND ITS RELATION TO THE BODY.—With reference to the relation of mind and matter, and the nature and source of mental phenomena, there are two theories, that of the *materialist* and the *spiritualist*. The materialist supposes that all the operations of the mind are but

"expresions of material changes in the brain;" that thus man is but a thinking machine, his whole conduct being determined by his original constitution, his character being formed *for* him and not *by* him, his actions being simply the result of the reaction of his cerebrum upon the impressions which called it into play. According to this doctrine, the highest elevation of man's *psychical* nature is to be attained by proper attention to those circumstances which promote his *physical* development. The arguments in support of this theory are :—1st, the dependence of the normal activity of the mind upon the healthy nutrition of the brain, and its proper supply of pure blood; 2nd, the peculiar effects of lesions of the brain upon the intellectual operations, as is seen in loss of speech, memory, etc., after severe injury to the head; 3rd, the production of mental imbecility as a result of disease in the parents, or defective nutrition in the offspring during childhood; and—4th, the complete perversion of the mind and moral feelings which is produced by intoxicating agents. Now, though this doctrine recognizes some great facts regarding the dependence of mental operations upon the organization and functional activity of the nervous system, yet there is beyond and above all this a *self-determining power* which can rise above the promptings of external suggestions, and which can suit external circumstances to its own requirements, instead of being completely subjugated by them.

The *spiritualist* regards the mind in the light of a separate immaterial existence connected with the body, but not in any way dependent upon it, except as deriving its knowledge of external things through its agency, and as making use of it to execute its determination so far as these relate to material objects. According to this theory, the operations of the mind, having no relation to those of the body, are never affected by its irregularities or defects of functional activity; and the mind, thus independent of the body, is endowed with a complete power of self-government, and is

responsible for all its actions. But nothing can be more plain than that the introduction of intoxicating agents into the system really perverts the action of the mind, and occasions many strange results at variance with its normal action. So that, however true it may be that there is something in our mental constitution beyond and above any agency which can be attributed to matter, the operations of the mind are in a great degree determined by the material conditions with which they are so intimately associated. The whole system of education recognizes the importance of external influences in the formation of the character; and it is the duty of every teacher to foster the development and promote the right exercise of that power by which each individual becomes the director of his own conduct.

Hence it will be seen that any attempt to bring mind and matter into the same category is attended with difficulty, since no relation of identity can exist between them. But although no relation of identity or analogy subsists between mind and matter, a very close relation may be shown to exist between *mind* and *force*, or between *mind-force* and *nerve-force*. In the phenomena of voluntary movements the will operates upon the nervous matter, and developes nerve-force, the transmission of which along the nerve trunks is the determining cause of muscular contraction. Here is evidence of the excitement of nerve-force by mental agency. The converse of this is equally true, viz., that mental activity may be excited by nerve-force. This is the case in every act in which the mind is excited through the instrumentality of the sensorium; the impression is first conveyed to the sensorium (or sensory ganglia), in which it produces a certain active condition of the nervous matter, which is the immediate antecedent of all consciousness—whether of emotions or ideas. And since the will can develope nerve-force, and as nerve-force can develope mental activity, there must be a *correlation* between the two forces, not less intimate than that which exists between nerve-force

and electricity. The nervous matter of the cerebrum is the material *substratum* through which the metamorphosis of nerve-force into mind-force, and mind-force into nerve-force is effected, and like all other changes, every act of the mind involves the disintegration of the nervous substance which ministers to it.

The *influence of the mind over the body* is a most remarkable phenomenon, and one well worthy of attention. Many of its effects are quite familiar ; for example, fear or great anxiety of mind produces a desire for frequent micturition, and not unfrequently the bowels are moved also. The announcement to the patient of the arrival of the accoucheur, suspends for a time the labor pains. The sight, or even the thought of very unpalatable medicine, produces nausea, and sometimes vomiting. Under the influence of the mind, opium pills have been known to produce catharsis, when the patient supposed that he had taken a cathartic. In this way also, persons have been much benefited, and in some instances entirely cured, by the simplest remedies. Much of the success of the homœopathist is no doubt due to this fact. In all modes of treatment, therefore, it is absolutely necessary to have the entire confidence of the patient. It has also been observed, that when the mind is directed to any tumor or growth of the body, its increase is greatly accelerated.

In consequence of the waste of nerve tissue during its activity, it is necessary that a periodical suspension should take place in order to permit of nutritive regeneration ; this is called *sleep*. In deep sleep there is a state of complete unconsciousness, and the body may remain for a considerable time motionless ; but the individual is capable of being aroused by external impressions. In this it differs from *coma*, which is generally the result of some pressure upon the brain, in which the patient is incapable of being aroused. The tendency to fall asleep is favored by a succession of dull, monotonous sounds, as a dull, prosy speech or sermon ;

or by sounds accompanied by gentle movements, as is seen in putting infants asleep. Another method is to close the eyes and fix the attention upon some object, or repeat a certain word until the mind becomes completely lost or unconscious. The average amount of sleep required by a healthy adult is about eight hours in twenty-four; children require more. On some occasions the sleep is more or less disturbed by *dreams.* These generally refer to something that has engaged the attention previously; but in some instances they would appear to indicate things that are to happen; at all events, there is in many instances a singular coincidence between dreams and occurrences which follow them. An uneasy or anxious state of mind is unfavorable to sleep. It is said that criminals under sentence of death sleep badly while they have hopes of a reprieve, but as soon as they are assured that their death is inevitable, they usually sleep more soundly.

Derangement of the digestive organs, or a disturbed state of mind, in some instances, gives rise to a dreaming state called *somnambulism.* In this state the individual acts as if he were awake, and as if all the phenomena presented to him were real. He answers questions rationally and with readiness; he walks with precision and avoids obstacles; yet, not unfrequently, accidents happen which show that he has not full command of his senses.

A state remarkably analogous to somnambulism may be induced in some persons, which has been called *mesmerism.* The production of this state requires the apparent influence of another individual, who looks directly in the face of the person experimented upon, and makes certain movements before him called *passes;* or the person is required to gaze steadfastly upon a piece of metal or other substance held in the hand, until a state of unconsciousness is induced. Remarkable statements have been made, implying that in these cases the faculties are very much exalted, and the person acquires powers of a superhuman kind. Such state-

ments, however, are made by those interested in such *séances*, or by those who are ignorant of the deception resorted to in order to obtain notoriety.

CRANIAL NERVES.

The cranial nerves include those nerves which arise from some part of the cerebro-spinal centre and are transmitted through foramina at the base of the brain. There are in reality twelve pairs of cranial nerves, but they are arranged in nine pairs in the following order from before backwards:—

1st	Olfactory	7th	Facial or portio dura
2nd	Optic		Auditory or portio mollis
3rd	Motor Oculi	8th	Glosso-pharyngeal
4th	Pathetic		Pneumogastric.
5th	Trifacial or trigemini		Spinal accessory.
6th	Abducens	9th	Hypoglossal.

The nerves of the 7th and 8th pairs are so combined in their distribution, that it is almost impossible to separate them in either their anatomy or physiology. The cranial nerves may be subdivided into four groups, according to the peculiar function of each, viz., 1st, *nerves of special sense*, as the olfactory, optic, auditory, the lingual branch of the trifacial, and part of the glosso-pharyngeal; 2nd, *nerves of common sensation*, as the greater portion of the fifth, and part of the glosso-pharyngeal; 3rd, *nerves of motion*, as the motor oculi, pathetic, part of the trifacial, abducens, facial, and hypoglossal; and 4th, *mixed nerves*, as the pneumogastric and spinal accessory.

The *olfactory nerve* arises from the cerebrum by three roots, and presents a bulbous enlargement which rests upon the cribriform plate of the ethmoid bone, from which delicate filaments are given off which supply the nose. It is the nerve of the special sense of smell. In structure it differs

from the other nerves, in being soft and grayish in color, and destitute of the white substance of Schwann.

Fig. 110.

External wall of the nose. *a*, Olfactory nerve ; *b*, olfactory bulb upon the cribriform plate of the ethmoid ; below is seen the distribution of the branches upon the upper and the middle turbinated bones ; *c*, fifth nerve with Gasserian ganglion ; *o*, its palatine branches.

The *optic nerve* is distributed to the eye, in which it expands to form the internal layer of the retina, and is the nerve of the special sense of sight. Division of the optic nerve produces total blindness and dilatation of the pupil, but does not destroy ordinary sensibility or paralyze muscular action.

The *auditory nerve* (*portio mollis*) is the special nerve of the sense of hearing. It conveys to the brain the sensation of sound, and is incapable of transmitting any other, being entirely destitute of ordinary sensibility. The *filaments* are distributed to the cochlea, semicircular canals and vestibule.

The *motor-oculi* is a nerve of motion, and is distributed to all the muscles of the eyeball, except the superior oblique and external rectus. It also supplies motor filaments to the *circular* fibres of the iris. In paralysis of this nerve, the upper eyelid falls down over the eye, so that it appears half closed (*ptosis*), the pupil is dilated and insens-

ible to light, the movements of the eyeball are nearly suspended, and the eye is directed outwards, owing to the action of the external rectus. Owing to the irregularity of the axes of the eyes, double sight is often experienced. The stimulus of light on the retina produces contraction of the circular fibres of the iris, and partial closure of the pupil. This is a reflex action, the stimulus being conveyed by the optic nerve to the brain, and thence reflected through the third nerve to the iris; consequently the iris ceases to act when either the optic or third nerve is divided or destroyed, or the nervous centre injured or compressed. The *radiating* fibres of the iris are supplied by filaments from the fifth cranial nerve and the ophthalmic or ciliary ganglion.

The *pathetic nerve,* the smallest of the cranial nerves, is also a nerve of motion distributed to the superior oblique muscle. When the nerve is irritated the muscle acts spasmodically, and its division causes paralysis and a loss of rotatory motion of the eyeball on its axis, and sometimes double vision

The *abducens* supplies the external rectus with motor power. Irritation of this nerve produces convulsion of the muscle, and the eye is turned outwards. Division or injury is followed by convergent *strabismus.*

The *trifacial nerve* closely resembles the spinal nerves. It arises by two roots an anterior, smaller or motor, and a posterior or sensory, which has a ganglion (the Gasserian ganglion) developed on it. The functions of this nerve are various; it is the great sensitive nerve of the head and face; the motor nerve of the muscles of mastication (except the buccinator), and its lingual branch is one of the nerves of the special sense of taste. This nerve, within the cranium, is divided into three branches—the *ophthalmic,* which passes through the sphenoidal fissure, the *superior maxillary,* which passes through the foramen rotundum, and the *inferior maxillary,* which passes through the foramen ovale. The first and second divisions are purely sensory;

the third division contains filaments of special sense, sensation and motion. It is the most intensely sensitive nerve in the body, and irritation of its sensory filaments is followed by intense pain. Any irritation to this nerve, or any of its branches, as *e. g.*, a carious tooth, may give rise to neuralgia of the corresponding side of the face, and in many instances one-half of the tongue is found covered with a white fur, while the other half is perfectly clean. Division of the fifth nerve produces loss of sensibility and motion in the parts supplied by it, and is followed by inflammation of the corresponding eye; the cornea becomes opaque, and a low destructive inflammation of the conjunctiva, sclerotic, and interior of the eye occurs, which usually goes on to complete and permanent destruction, and sloughing of the organ; the senses of smell, hearing, and taste, are at the same time impaired or lost. Injury to the fifth nerve, or some of its branches, is sometimes followed by total blindness in the corresponding eye. These phenomena may be due to the *trophic* influence of the nerve on these organs, and the defective nutrition which follows its injury. Paralysis of the third nerve may also follow neuralgia of the fifth nerve.

The *facial nerve* (*portio dura*) supplies all the muscles of the face, the platysma, buccinator, the muscles of the external ear, digastric and stylo-hyoid, the palate, stapedius and laxator tympani muscles. It also supplies the parotid gland, and through the *chorda tympani* it gives branches to the submaxillary gland, lingualis, and other muscles of the tongue. It is a nerve of motion, and not of sensation, and therefore its division, which was formerly resorted to in cases of *tic douloureux*, is incapable of relieving neuralgic pains, but is followed by paralysis of the muscles which it supplies. Division or paralysis of the facial nerve prevents the eye from being closed, and its continued exposure to the air, and particles of dust, is apt to produce inflammation. The sense of hearing, taste, and smell may also be impaired. In *facial paralysis* there is an absence of

expression on the affected side, the angle of the mouth is lower, and the eye has an unmeaning stare. In drinking, the fluids flow out at the corner of the mouth, and the food lodges between the cheek and gums. When the tongue is paralyzed, it is drawn to the sound side when protruded, in consequence of the paralysis of the muscles on the affected side.

The *glosso-pharyngeal nerve* is distributed to the tongue and pharynx, being the nerve of sensation to the mucous membrane of the pharynx, the fauces and tonsil; of motion to the pharyngeal muscles, and a special nerve of taste to the posterior part of the tongue. It also supplies filaments to the fenestra ovalis and rotunda, the Eustachian tube, carotid plexus, and spheno-palatine ganglion. The tongue is supplied by two special nerves—the lingual branch of the fifth, and the glosso-pharyngeal; the former supplies the anterior and lateral parts of the superior surface, and the latter the posterior and lateral parts. This may be proved by division of either of these nerves, when the sense of taste is lost in the part supplied by the injured nerve.

The *hypoglossal nerve* is a nerve of motion. It is distributed to the muscles which belong to the hyoid bone and tongue, and is concerned in articulation. Irritation of this nerve produces contraction in the muscles supplied by it, and is sometimes attended with pain, the sensibility having been borrowed from the nerves with which it communicates. Its division or injury is followed by paralysis.

The *pneumogastric nerve* is one of the most remarkable and important in the body. It supplies the pharnyx, epiglottis, glottis, larynx, trachea, œsophagus, heart, lungs, liver, stomach and spleen. It possesses motor, sensitive and sympathetic or ganglionic nerve fibres, and is therefore regarded as a *triple-mixed nerve.* The *pharyngeal* branch is the motor nerve of the muscles of the pharynx; the *superior laryngeal* is chiefly sensory, and supplies the mucous membrane of the larynx; the *inferior* or *recurrent laryngeal*

is for the most part motor, and supplies the muscles; the *œsophageal branches* supply its muscular tissue; the *cardiac* branches constitute a channel through which the influence of the central organs and the emotions of the mind are transmitted to the heart; the *pulmonary* branches form a channel through which the impressions on the lungs are conveyed to the medulla oblongata; the motor filaments of the pneumogastric nerve supply the motor influence by which the function of deglutition is performed. In the functions of the larynx, the sensitive filaments supply that acute sensibility by which the glottis is guarded against the ingress of foreign bodies or irrespirable gases. These are instances of "reflex action."

The cardiac branches of the pneumogastric have an *inhibitory* or restraining influence upon the heart (p. 212). When divided the heart's action is increased; while on the other hand when stimulated, as by a galvanic current, the heart's action is diminished, or if a strong current be used, it is arrested altogether in diastole.

Division of the pneumogastric nerve or its inferior laryngeal branches produces *loss of voice*, by paralyzing the muscles of the larynx which act upon the vocal chords. Division of the pneumogastric nerves is also followed by a *diminution of the frequency of the respiratory movements.* In young animals it is often quickly fatal, owing to the closure of the glottis, which is due to the yielding nature of the cartilages; but in older animals death ensues more slowly, owing to the rigidity of the cartilages which surround the glottis. Death takes place in from one to six days after the operation, and is caused by the engorgement of the lungs. They are commonly very much congested, nearly solid, and the bronchial tubes are filled with a frothy, bloody fluid, and mucus. This is due in part to the slowness of the respiratory movements, the imperfect aëration of the blood, and the accumulation of carbonic acid in the air cells, and also in part to the paralysis of the blood-vessels themselves.

Since respiration is still carried on after the division of the pneumogastric nerves, it is evident that though they are the chief agents by which the respiratory stimulus is conveyed to the medulla oblongata, they are not the only ones.

The secretion of gastric juice is temporarily suspended after division of the pneumogastric nerve, and the digestive function is more or less disturbed in various ways, but the sensations of hunger and thirst still remain. In many instances the food taken by the animal never reaches the stomach owing to the paralysis of the œsophagus, but is regurgitated in a few moments afterwards—this action being excited by the influence of the sympathetic nerves. The muscular coat of the stomach is also paralyzed by section of this nerve.

Division of the pneumogastric nerve also interferes with the proper function of the liver, and irritation of the central extremity of the divided nerve is followed by the rapid development of sugar in this organ, probably by causing paralysis of the hepatic vaso-motor nerves.

The *spinal accessory nerve* arises partly from the medulla oblongata, and partly from the spinal cord. It is essentially a motor nerve; but it also contains sensitive fibres, and is connected with the ganglion of the pneumogastric. From these circumstances it may be regarded as a *mixed nerve.* It supplies the sterno-mastoid and trapezius muscles, and it is also connected with the vocal movements of the glottis. If the spinal accessory nerve be divided on both sides, or its branch of communication with the pneumogastric nerve, *the voice is instantly lost,* the animal being incapable of uttering a single sound. Division of the pneumogastrics or their inferior laryngeal branches, paralyzes both the movements of respiration and phonation, while section of the spinal accessory paralyzes the movements of phonation alone, or those muscles which narrow the glottis and approximate the vocal chords, the movements of respiration, which open the glottis and sepa-

rate the vocal chords remaining intact. It may be stated as a general law, that when any part of the body receives nervous filaments from two different sources, it is for the purpose of enabling it to perform two different functions. This is exemplified in the muscles of the larynx. These muscles are concerned in the respiratory movements, the nervous stimulus for which is conveyed by the facial, hypoglossal, and pneumogastric nerves; but they are also concerned in the formation of the voice, the nervous influence for which is conveyed by the spinal accessory.

SYMPATHETIC NERVOUS SYSTEM.

The sympathetic system (or nervous system of organic life), is so named because it was formerly supposed to be the system through which distant organs manifested sympathy with each other in morbid action. It consists of a series of ganglia connected together by intervening cords, extending on each side of the spinal column, from the base of the skull to the coccyx; some of the ganglia may also be traced into the cranium. These two gangliated cords lie parallel to one another as far as the coccyx, where they communicate through a single ganglion—*ganglion impar.* It is also stated that they communicate at their cephalic extremity through a small ganglion, situated on the anterior communicating artery—*the ganglion of Ribes.*

They are arranged as follows:—In the cephalic region there are four ganglia on each side (and the ganglion of Ribes); in the cervical region, three; in the dorsal region, twelve; in the lumbar region, four; in the sacral region, five; and in the coccygeal region, one—the ganglion impar. Each ganglion may be regarded as a distinct centre from and to which, branches pass in various directions, as follows —1st, communicating branches between the ganglia; 2nd, communicating branches to the cerebral or spinal nerves; 3rd, primary branches of distribution to the arteries in the vicinity of the ganglia, to the viscera, or to other ganglia in

the thorax, abdomen, and pelvis. The latter consist of two kinds of nerves, the *sympathetic* and *spinal*, and have a remarkable tendency to form intricate plexuses which surround the blood-vessels, being conducted by them to the viscera. Many of these primary branches, however, pass to a series of ganglia in the thorax and abdomen, the chief of which are the cardiac and semilunar ganglia. Fibres of the sympathetic are distributed to the nonstriated muscular tissue of the intestines and other hollow organs, and to the blood-vessels (vaso-motor nerves); to the heart—excito-motor; and to the various glands. Centripetal fibres also pass to the vaso-motor centre in the medulla oblongata. The difference between the cerebro-spinal and sympathetic nerves has been already stated (p. 282). Both kinds of nerves are distributed to all parts of the body.

The ganglia of the sympathetic system are regarded by some writers as reservoirs of nervous force, which they equalize and correctly balance, by storing up all transient excesses, and furnishing all transient deficiencies. In structure they are essentially similar, containing nerve fibres entering and emerging, nerve cells, or ganglion corpuscles, and other corpuscles that appear free (Fig. 98). Complex as the whole sympathetic system appears, however, each of its parts exhibits a wonderful simplicity; for each ganglion with its afferent and efferent nerves forms a simple nervous system, and might serve for the illustration of all the nervous actions with which the mind is unconnected.

Function of the Sympathetic System.—The sympathetic nervous system is endowed with sensibility and the power of exciting motion exactly similar to the cerebro-spinal system; but in the exercise of these functions it is less active. When irritation is applied to a sensitive nerve in one of the extremities, the evidence of pain or motion is acute and instantaneous; while, on the other hand, irritation of the sympathetic nerve is felt distinctly enough, but is only responded to after somewhat prolonged application.

This comports very much with what is known of those organs, supplied chiefly by the sympathetic system, *e. g.*, the movements of the stomach and intestines are not felt under ordinary circumstances; but any excessive or prolonged irritation may cause them to be exceedingly painful. The general processes which the sympathetic system appears to influence are those of involuntary motion, secretion, and nutrition. The ganglia have the power of *conducting, transferring* and *reflecting* impressions made on them similar to the cerebro-spinal system, and the sympathetic nerves are conductors of impressions. Parts chiefly supplied with sympathetic nerves are usually capable of only involuntary movements, as, *e.g.*, the heart, stomach and intestines, and these parts may still continue to move for a short time after the death of the animal. Thus, in the mammalia the heart continues to beat for one or two minutes after it is taken from the body; in reptiles and amphibia for several hours; and the peristaltic action of the bowels is continued for a prolonged period.

Division of the sympathetic nerve produces immediately a *vascular congestion* in the parts supplied by it. This was first pointed out by Bernard; he divided the sympathetic nerve of a rabbit in the middle of the neck, and found that congestion of the corresponding side of the head immediately followed, which was most distinctly marked in the ears; and the venous blood returning from the part had a ruddy hue. The pupil is also contracted and the eye partially closed, owing to the increased sensibility of the retina from vascular congestion of the parts. The congestion appears to be caused by the dilatation of the vessels and consequent increased rapidity of the circulation, for when any irritation is applied to the divided end of the nerve, the vessels contract and the congestion disappears. The vessels therefore appear to be under the influence of the sympathetic nerves, which accompany them in all their varied distributions and minute ramifications. They are

distributed to the muscular coat of the vessels, the function of which is to regulate the supply of blood to the various organs. The congestion of the vessels caused by division of the sympathetic nerve is also accompanied by an *elevation of temperature* in the affected part; this increase of heat has been found as high as 8° to 9°F., and like the vascular congestion, to which it is due, may last a considerable length of time. The sympathetic system has also some connection with the special senses, especially with the sense of sight. The ophthalmic ganglion gives off small branches to the iris, and receives a communicating motor branch from the third nerve. The contraction of the pupil under the influence of light, and its dilatation in the dark, are affected through this ganglion.

With reference to the influence of the sympathetic nerve in the processes of secretion and nutrition, little is known except that it is in great measure connected with the supply of blood to the parts. It serves as a medium of reflex action between the sensitive and motor portions of the digestive, excretory and generative organs, and it also takes part in reflex actions which may be referred to the cerebro-spinal system; for example, the contact of food in the intestine excites, through the medium of the sympathetic nerves, a peristaltic movement in the muscular coat. The irritation produced by undigested food in the alimentary canal may give rise to diarrhœa, or it may produce, through the medium of the sympathetic and cerebro-spinal systems, epileptic convulsions, especially in children.

CHAPTER XIV.

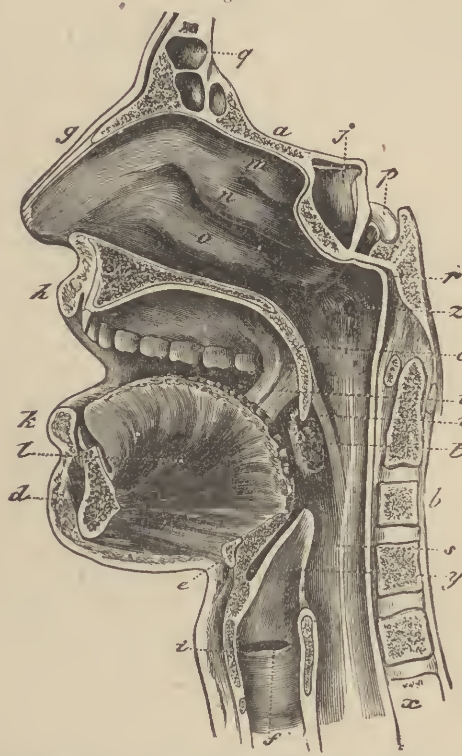
THE SPECIAL SENSES.

The special senses are *five* in number, *smell, sight, hearing, taste*, and *touch*. The last two have been already casually referred to.

SMELL.—The sense of smell is limited to the nasal cavity, and is confined to that portion on which the olfactory nerves are distributed, viz., the roof, the septum, and the upper part of the lateral walls (Fig. 110, p. 330). The nasal cavity is lined by mucous membrane, called also the pituitary or Schneiderian membrane; it is covered with columnar ciliated epithelium, except in the upper part and roof—the olfactory region, in which it is non-ciliated. The filaments of the olfactory nerves pass through the foramina in the cribriform plate of the ethmoid bone, and are distributed beneath the mucous membrane; they convey the sensitive impressions made by odoriferous particles upon the mucous membrane to the sensorium, which give rise to the sense of smell. The sense of smell is confined to the olfactory nerves, as has been shown by their division, after which the sense of smell is completely lost, while sensibility still remains, and their irritation is not followed by any muscular action, either of a direct or reflex character. Division of the fifth nerve, or some of its branches, which supply the nose, is followed by impairment of the sense of smell. It cannot be inferred from this, however, that it is a nerve of the special sense of smell; the result is to be attributed to the dry and otherwise deranged state of the mucous membrane, occasioned by the altered nutrition of the parts.

The *meatuses* and *sinuosities* of the nasal cavities are well adapted not only to increase the extent of mucous surface, but also to impede the air and odoriferous particles

Fig. 111.



Nose, mouth and pharynx; a, cribriform plate; b, spine; c, soft palate; d, lower jaw; e, hyoid bone; f, cavity of the larynx; l, tongue; m, n, o, superior, middle and nferior turbinated bones, beneath which are the meatuses; q, frontal sinuses; s, narrow part of the pharynx; t, tonsil; u, anterior pillar of the fauces; v, posterior pillar; y, the epiglottis; z, orifice of the Eustachian tube.

which it may contain, in their passage through them, so as to bring them into more immediate contact with the mucous surface, by means of which their peculiar characters are more fully impressed on the olfactory nerves. The *frontal sinuses* are supposed to assist in the extension of the sense of smell; but since they do not receive filaments from the olfactory nerves, and are largely developed in some animals,

as the grey-hound, in which the sense of smell is by no means acute, it is highly improbable. The sense of smell varies much in different individuals, and, like all the senses, may be improved by frequent practice.

It may become blunted by long-continued exposure to one kind of smell, as, for example, the effluvia of the dissecting room. Various odors also affect it differently, as musk, asafœtida; and some produce nausea and even fainting.

The irritation produced by the contact of substances which act mechanically or chemically on the mucous membrane, as ammonia, nitrous acid, etc., must not be confounded with the sense of smelling. These impressions are conveyed to the sensorium by the fifth nerve, which is the nerve of sensation. The sense of smell may be impaired or destroyed by a dry state of the mucous membrane; by the obstruction of the air passages, as in the case of polypi; by chronic inflammation, as catarrh, ozæna, and by the frequent use of snuff, which tends to blunt its acuteness and cover the surface with its particles.

Besides the olfactory and fifth nerve, there are some filaments from the spheno-palatine ganglion distributed to the nose. The function of these is not very well known; but from the connection with the fifth nerve and the sympathy between the sense of smell and taste, they are probably nerves of *associate function.* All animals have not the same facility for perceiving odors. Carnivorous animals have the faculty of detecting readily, animal odors, and tracking other animals by the scent. Herbivorous animals, on the other hand, possess the power of detecting readily the odor of vegetable matters. The sense of smell in man is not so acute as in most animals, but it is more uniform and extended. The extreme delicacy of the sense of smell is shown by the fact, that $\frac{1}{30,000,000}$ of a grain of musk may be distinctly smelt. Some odors are pleasant, and some are offensive, but the cause of the difference is not known; many

odors also which are agreeable to one individual, are offensive to another. Certain sensations also frequently produce a smell, for example, electricity produces a smell like phosphorus, and the negative pole of the battery applied to the nose a smell of ammonia , while the positive pole produces an acid odor. In disease or derangement of the olfactory nerve, *subjective* sensations of smell frequently occur.

SIGHT.

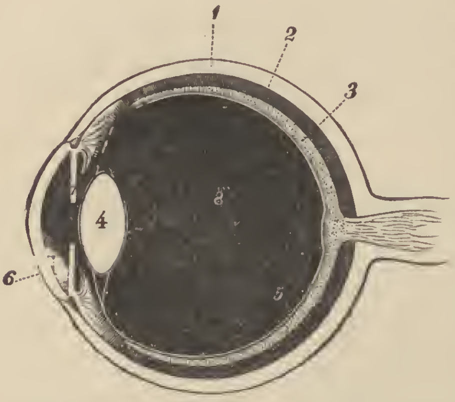
The eye is the organ of the special sense of sight, and is situated in the cavity of the orbit. It is spherical in form, having the segment of a smaller and more prominent sphere engrafted on its anterior surface. It measures about an inch in the antero-posterior diameter, and a little less transversely. It consists of *three coats*; an outer, consisting of the *sclerotic and cornea*; a middle, consisting of the *choroid coat, ciliary processes,* and *iris*; and an internal, the *retina*; and *three* refracting media,—the *aqueous humor*, the *vitreous humor*, and the *crystalline lens and capsule.*

The *sclerotic* is a dense fibrous membrane, thicker behind than in front, which covers the posterior five-sixths of the eye. It is continuous in front with the cornea, and behind with the sheath of the optic nerve, which is derived from the dura mater. Behind, it is pierced, a little to its nasal side, by the optic nerve, around which are openings for the passage of the ciliary vessels and nerves.

The *cornea* projects forwards, somewhat resembling a watch-glass, and covers the anterior sixth of the globe. It is concavo-convex, the degree of curvature varying in different individuals. and in the same individual at different periods of life, being generally more prominent in youth than in advanced age. This differencein the curvature influences considerably the refractive power of the eye, and is partly the cause of *long* and *short-sightedness.* The cornea in health is perfectly transparent, contains no bloodvessels, and consists of five layers;—the *cornea proper*,

a central fibrous structure; in front of this, the *anterior elastic lamina*, covered by the *conjunctiva*; behind, the *posterior elastic lamina*, covered by the *lining membrane* of the *anterior chamber* of the eyeball. The conjunctival epithelium consists of several layers of cells, the superficial ones being flattened and scaly, and the deeper ones columnar or cylindrical. The anterior and posterior elastic laminæ, consist of a thin, transparent homogenous membrane, and have a tendency to curl upon themselves, with the attached surface inwards, when separated from the cornea proper. The cornea proper consists of finely fibrillated bundles of transparent connective tissue, in the spaces of which the branched cornea corpuscles lie. The branched cornea corpuscles are capable of passing from one space to another by their amœboid movement. When this tissue is injured in any way, it presents an opaque milky appearance. The posterior elastic lamina and the single layer of epithelium which covers it, is known as Descemet's membrane. The nerves that supply the cornea are derived from the ciliary nerves.

Fig. 112.



Vertical section of the eye ball. 1, sclerotic; 2, choroid; 3, retina; 4, crystalline lens; 5, hyaloid membrane; 6, cornea; 7, iris; 8, vitreous body.

The *choroid* is a thin, highly vascular membrane, of a dark color, which covers the posterior five-sixths of the globe, and is situated between the sclerotic and retina. It is pierced behind by the optic nerve, and terminates in front at the ciliary ligament, where it bends inwards and forms

the ciliary processes. It is composed of *three layers*, the *external*, which consists of the larger branches of the ciliary arteries, but chiefly the veins and some star-shaped pigment cells; the *middle*, which consists of a fine capillary plexus (tunica Ruyschiani); and the *internal* or *pigmentary* layer, which is made up of a single layer of hexagonal cells, loaded with pigment granules, so arranged as to resemble tesselated epithelium. The principal use of the choroid coat is to absorb the rays of light which pass through the retina, and prevent them from being thrown back to dazzle the images formed on the retina. In perfect Albinoes the cells contain no pigment, and they can see best in moderate light, or twilight.

The *ciliary processes* are formed by the folding inwards of the middle and internal layers of the choroid around the margin of the lens, behind the iris. They vary in number from sixty to eighty, and are about one-tenth of an inch in length. They are similar in structure to the corresponding layers of the choroid.

The *iris* (ιρις, a rainbow) is a thin, circular-shaped contractile curtain which regulates the quantity of light transmitted to the retina. It is suspended in the aqueous humor behind the cornea, and in front of the lens, and presents, at the nasal side of its centre, a circular opening, the *pupil*, for the transmission of light. It separates the cavity for the aqueous humor into two parts, the anterior and posterior chambers. It consists of a *fibrous* stroma, *muscular* fibres, and *pigment cells*. The *muscular tissue* is involuntary and consists of *circular* fibres which surround the pupil, and *radiating* fibres which converge from the circumference of the iris to the margin of the pupil; the former contract the pupil, the latter dilate it. The circular fibres are supplied by the third cranial nerve, and the radiating fibres by the fifth and sympathetic (p. 331). The *fibrous* tissue forms a delicate net-work in which the pigment cells, vessels and nerves are contained. The *pigment cells* are found in the

stroma, and also as a distinct layer on the anterior and posterior surfaces, and give rise to the different color of the iris in different individuals. On the posterior surface of the iris there are several layers of round cells filled with pigment granules. These are called the *uvea*, from their resemblance in color to a ripe grape. The iris is connected to the choroid and to the external coat of the eyeball at the junction of the sclerotic and cornea, by means of a circular band of white fibrous tissue, the *ciliary ligament*. At its point of junction with the sclerotic a minute canal is seen, the *sinus circularis iridis.*

The middle coat of the eye is also connected to the external, by means of a circular band of nonstriated muscular

Fig. 113.

Posterior part of the retina as seen with the ophthalmoscope.

tissue, the *ciliary muscle.* It is about one-eighth of an inch broad, thicker in front than behind, and is attached anteriorly, or *arises* at the point of junction of the sclerotic and

cornea, and passing backwards is *inserted* into the choroid in front of the retina. By its action it draws the ciliary processes towards the line of junction of the sclerotic and cornea, and compresses the lens, increasing the curvature of its anterior surface, and in this way adjusting the eye to the vision of near objects.

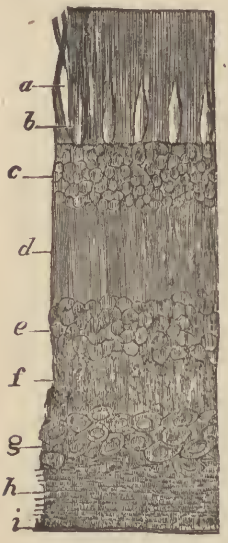
The *retina* is the delicate nervous membrane upon the surface of which the images of external objects are received. Behind, it is continuous with the optic nerve; in front it terminates by a serrated margin, the *ora serrata*; its inner surface is in contact with the hyaloid membrane which surrounds the vitreous humor; externally it is in relation with the choroid. In the centre of the posterior part, corresponding to the axis of the eye, is seen a round, yellowish spot $\frac{1}{25}$ of an inch in diameter (1 mm.) called the *limbus luteus*, or the yellow spot of Sömmering. In its centre is a minute depression, the *fovea centralis.* The retina in this part is very thin, and the sense of vision is most perfect. About one-tenth of an inch to the inner side of this spot is seen the entrance of the optic nerve; here the power of vision is entirely absent.

The retina is composed of *three* principal layers, together with blood-vessels and delicate areolar tissue; the *external* or *columnar*; the *middle* or *granular*; and the *internal* or *nervous* layer; each of these is again subdivided into sub-layers, as shown in Fig. 114.

The *external* or *columnar layer* is exceedingly thin, and consists of solid columnar rod-like bodies, with cones filled with fluid interspersed at regular intervals (a, b). These are separated from the granular layer by a transparent homogeneous membrane, the *membrana limitans externa.* The *middle* or *granular layer* is transparent, finely fibrillated and comprises one-third of the thickness of the retina. It consists of two layers of rounded nuclear particles (c, e) separated by an inter-granular layer (d). The external granular layer is the thicker, and its particles are *globular*,

and connected with the rods and cones by fibres passing through the membrana limitans. The internal granular layer is the thinner, and its particles are flattened, looking like pieces of money seen edgeways, hence called the *nummular* layer. These cells are, however, *bipolar* sending one process outwards through the inter-granular layer, and another inwards through the molecular layer, to reach the expansion of the optic nerve. The *internal* or *nervous layer* is thin, semi-transparent and consists essentially of the expansion of the terminal fibres of the optic nerve, and nerve cells. It also presents *three* layers; the *molecular* or finely granular layer, resembling the molecular matter found in the gray substance of the brain and spinal cord; the layer of ganglion cells or *cellular* layer, which consists of multipolar cells, some of the processes of which pass outward to the molecular layer and others inwards to the fibrous layer; and the *fibrous* layer or expansion of the optic nerve. The nerve fibres of this layer consist only of the axis cylinder, and some of them become continuous with the prolongations of the ganglion cells. The inner surface of the retina is lined by a transparent homogeneous membrane, which separates it from the vitreous body, the *membrana limitans interna*. Blood-vessels are only found in the internal layer, and extending to the internal granular stratum of the middle layer. In the external or rod-and-cone layer of birds, the cones predominate, while in man the rods are more numerous. In nocturnal animals, as the owl, bat, mole, etc., the cones are entirely absent. In the fovea centralis, where vision is most acute,

Fig. 114.



Vertical section of the human retina. a, Rods; b, cones, resting upon the membrana limitans externa; c, external granular layer; d, intergranular layer; e, internal granular layer; f, molecular layer; g, layer of ganglion cells; h, expansion of the optic nerve fibres; i, membrana limitans interna.

all the layers of the retina are thinner except the rods and cones which are increased, from which it would appear that these are more especially concerned in the function of vision.

The *aqueous humor* occupies the anterior part of the globe, and completely fills the anterior and posterior chambers of the eye. It is a clear, thin fluid, having an alkaline reaction, which is due to the presence of chloride of sodium. In the adult, the anterior and posterior chambers communicate through the pupil; but in the fœtus, before the seventh month, the pupil is closed by the membrana pupillaris. The persistence of this membrane sometimes occasions congenital blindness.

The *vitreous humor* occupies the posterior four-fifths of the globe. It is perfectly transparent, of the consistence of jelly, and consists of numerous layers of simple membrane with the intervening spaces filled with fluid. It is surrounded by the hyaloid membrane, and is hollowed out in front for the reception of the crystalline lens. It refracts the rays of light, and fills the globe of the eye so as to keep the retina at a proper distance from the lens. The vitreous humor contains some salts and a little albumen. In the fœtus, a minute artery passes through the centre to the posterior part of the capsule of the lens, the *arteria centralis retinæ;* but it disappears in the adult.

The *crystalline lens,* enclosed in its capsule, is situated in front of the vitreous humor and behind the pupil. The *capsule* is a transparent brittle membrane, highly elastic, and is disposed to curl inwards upon itself when ruptured. It surrounds the lens, to which it is connected by a layer of nucleated cells, and is held in position by the *suspensory ligament,* which connects it to the anterior margin of the retina. The suspensory ligament consists of two layers blended together; the *outer,* a milky, granular layer, comes in contact with the inner surface of the ciliary processes; the *inner,* is an elastic transparent membrane. This liga-

ment forms part of the boundary of the posterior chamber of the eye; its posterior surface is separated from the hyaloid membrane by a triangular interval—the *canal of Petit.* This canal is about one-tenth of an inch wide, bounded in front by the suspensory ligament, behind by the hyaloid membrane, and the base is formed by the capsule of the lens.

The *lens* itself is a transparent double convex body, being more convex behind than in front. It measures about four lines transversely and three lines from before backwards. It appears to consist of concentric laminæ, like the coats of an onion, the central ones forming a hardened nucleus. It also appears to consist of three triangular segments; this is readily demonstrated by boiling, or immersing it in alcohol. The laminæ consist of minute parallel fibres, hexagonal in shape, the edges being dentated and fitting into each other, and are about $\frac{1}{5000}$ of an inch (5 mmm.), in diameter. The refracting media of the eye are the cornea, aqueous humor, crystalline lens,and the vitreous humor.

There are two forms of the lens in the human eye, viz., the *concavo-convex* or *meniscus,* as the cornea; and the *double convex,* as the crystalline lens. The essential parts of the eye, appear to be: 1st, a dark coat to absorb the rays of light—the choroid; 2nd, a nervous expansion to receive and transmit to the brain the impression of light—the retina; 3rd, a concavo-convex lens to collect the rays of light from the object and direct them inwards, and a double convex lens to collect the rays of light and bring them to a focus, so as to form a correct image on the retina—the cornea and the lens; 4th, a contractile curtain with a central opening, to regulate the quantity of light entering the eye—the iris. The eye is thus a simple optical instrument, endowed with vitality, and acting as required without assistance. It is abundantly supplied with blood-vessels. In addition to the conjunctival vessels, there

are the vessels of the sclerotic, choroid, iris and retina. The latter are derived from the short, long, and anterior ciliary arteries, and the arteria centralis retinæ.

PHENOMENA OF VISION.—In order fully to understand the physiology of vision, it will be necessary to refer briefly to some of the laws which regulate the transmission of light.

1st,—Light travels in parallel rays through a medium of uniform density.

2nd,—When the rays meet with a medium of increased density, they become refracted, or changed in direction, towards a line which falls perpendicularly to the surface of the body which they enter.

3rd,—When the rays of light meet with a medium of diminished density, they are refracted from the perpendicular line.

4th,—When the rays of light fall upon a convex lens, they are collected; and if this be a double convex body, they come to a point or focus at a certain distance, depending on the degree of convexity of the lens; the greater the convexity the shorter the distance and, *vice versa*. The image formed by the refraction of the rays of light in coming to a point or focus will be an inverted one.

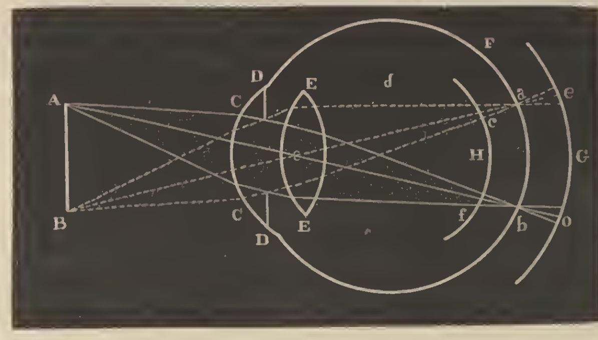
5th,—If the convexity of the lens be too great, the focus will be formed in front of the mirror or reflecting body. If too slight, the focus will be formed beyond it.

Vision is accomplished by the formation of an image of the object looked upon, on the internal surface of the retina. The impression made upon this produces a sensation, which is conveyed to the sensorium by the optic nerve, and the mind takes cognizance of it.

The image is formed in the following manner:—The rays of light are reflected from the object (A. B.), and impinge on the outer convex surface of the cornea (C. C.), through which they pass, becoming refracted towards the perpendicular. Those which fall on the circumference of

the cornea impinge upon the iris, and are reflected, showing the color of this structure; those which pass nearer its

Fig. 115.



centre, converge and enter the pupil. They now penetrate the crystalline lens (E. E.), by means of which they are still further converged, their convergence being completed by their passage through the vitreous humor, and are brought to a focus on the inner surface of the retina (a. and b.). If the retina be not at F., but at G. or H., certain luminous spots, e and o, or c and f, will be seen; for at H the rays have not yet met, and at G they have crossed and are again diverging. Since rays of light come from all points of the object, and are refracted in their passage, they must cross each other, and thus the image of the object on the retina (F), will be inverted, but this is corrected by the sensorium. The angle of crossing is called the *visual angle.*

Accommodation of the Eye to Vision.—It is quite evident that some arrangement of the refractive parts of the eye is necessary to adapt it to the vision of near and distant objects. The precise manner in which this accommodation is effected is a disputed point; some maintain that it is due to an alteration in the position of the lens; while others regard it as being due both to an alteration in the position and shape of the lens. The eye, in its normal state, is accommodated for distant vision, under the guidance of the recti muscles; this may be called its *passive* condition. The

active accommodation of the eye for the vision of near objects is caused by the advance of the crystalline lens towards the cornea, and also by the increased convexity of its anterior surface. It is advanced towards the cornea chiefly by the action of the *ciliary muscle*, and partly by the compression exercised upon the posterior three-fourths of the eyeball by the recti muscles. It may therefore be inferred that the recti muscles adapt and adjust the eye for ordinary vision; while the ciliary muscle may be regarded as the *fine adjuster*, which regulates the eye for the vision of near or very small objects.

The rays of light which pass through the margin of a lens are more refracted than those which pass through the centre, and owing to this unequal refraction the rays do not all meet at the same point. This defect is called *spherical aberration*. The formation of *distinct* and *correct* images on the retina is favoured by the action of the pupil, which prevents the rays of light from passing through any part of the lens but its centre, and thus preventing any tendency to *spherical aberration*. In optical instruments, as the microscope, telescope, etc., spherical aberration is prevented by the use of a diaphragm with a circular aperture, which shuts out all the marginal rays. Distinctness of vision is further secured by the black coating of pigment on the inner surface of the choroid, which absorbs any rays of light which may be reflected within the eye, and prevents them from being thrown back again upon the retina, so as to produce dazzling of the image there formed.

When a ray of light passes through an ordinary lens it is partly decomposed into its elementary colors, and a colored margin appears around the image owing to the unequal refraction of the elementary colors. This is called *chromatic aberration*, and is corrected in optical instruments by the combination of two or more lenses, differing in shape and density. The combination usually consists of two lenses of unequal refraction, a convex lens made of crown glass and

and a concave one of flint glass, but the number may be varied to suit the circumstances. Such combinations of lenses are called *achromatic.* The unequal refractive powers of the different media of the eye prevent chromatic aberration. If a ray of white light be passsed through a prism the different colors are refracted in different degrees, and a colored band appears, called the *spectrum,* arranged as follows: *violet, indigo, blue, green, yellow, orange* and *red.* The violet rays are most refrangible; the red the least; hence the image of a small white object appears as if surrounded with a yellowish or bluish fringe, because it cannot be accurately focused on the retina, This is called *irradiation.* For this reason a white figure on a black ground appears larger than a black one of the same size on a white ground.

The inverted image of any bright object, as the windows of the room may be distinctly seen in the eye of any albino animal, as a white rabbit; or if an opening be made at the superior surface of the eye so that the retina can be seen through the vitreous humor, a reversed image of any bright object may be seen on the posterior wall of the eye. Impressions once produced on the retina *remain for a short time* afterwards; their duration depending on the intensity of the impression they have left. A momentary impression of moderate intensity continues about one-eighth of a second. This is the reason why the act of winking does not interfere with the continuous vision of surrounding objects. The spectra which remain on the retina after viewing colored objects are always of the opposite or *complemental* color; *e. g,* the spectrum of a red object is green, that of violet, yellow, etc. This is because the retina becomes fatigued by the color looked at; but remains sensitive to the other rays.

There is in front of the eye a certain space within which objects are perceived, and beyond which nothing can be distinctly seen; this is called the *circle* or *field of vision*

and varies in extent in different circumstances. For example, if the eye is intently fixed upon one word in the middle of the page, this word and those that immediately surround it, which are in the circle of vision, are distinctly visible, while those at the circumference are imperceptible while the eye remains fixed. It is largest when the view is not confined to any near object.

The distinctness with which an object may be seen, appears to depend largely upon the number of rods and cones covered by the retinal image, hence, the nearer an object is to the vision of the eye, the more distinctly are its details seen. The images of two points require to be at least $\frac{1}{12000}$ of an inch (2 mmm) apart, in order to be distinguished separately. That portion of the retina which corresponds to the entrance of the optic nerve is insensible to light, and is called the *blind spot.* It we close the left eye, and direct the right steadily upon the circular spot here shown, while

the page is about six inches from the eye, both marks are visible. If the distance be gradually increased, the cross disappears from view, and if the book be still further removed, it comes in sight again.

The eye, in the uneducated state, cannot comprehend the properties of the objects seen, as color, form, etc., or the distance of the object; this is acquired by experience.

Simultaneous Action of the two Eyes.—Although an image of the object is formed on each retina, yet the impression of the object conveyed to the mind is single. This is, no doubt owing to the fact that the image is formed on identical points of both retinæ, giving rise to but one sensation, and the perception of a single image—the result of a mental act. This unity of action may be favoured by the continuation of the optic filaments across the anterior part of the *chiasma* of the optic nerve, but is not dependent on it; for, if the visual axis of one eye be altered, objects are seen double.

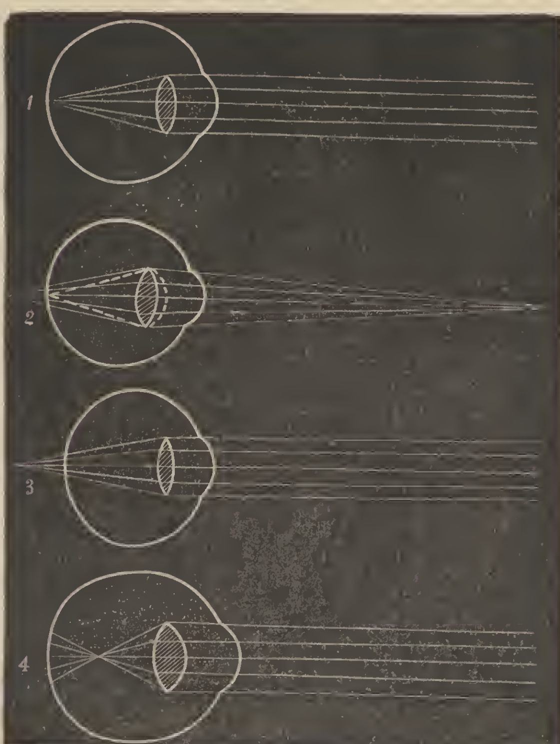
This may be demonstrated by pressing the eyeball on one side with the finger in order to rotate it upon its axis, while the eyes are fixed upon some object, as a book or lamp; two images of the object are seen as in *diplopia* from strabismus. This is owing to the formation of images of the objects on different parts of the two retinæ. The power of combining the two images is subservient to the faculty of obtaining a proper conception of bodies raised in relief. When a solid object as a cube is viewed, a different perspective of it is seen by each eye, and more of the surface of the body is seen than if viewed with one eye; in other words a *stereoscopic* effect is produced.

DEFECTS OF VISION.—The normal, or *emmetropic* eye brings parallel rays of light exactly to a focus on the retina (Fig. 116, 1) and all objects except near ones (within 20 feet), are seen without any effort of accommodation. In looking at near objects the eye is accommodated by the action of the ciliary muscle, and the rays which would otherwise meet behind the retina are correctly focused upon it, (Fig. 116, 2, dotted lines). The defects of vision are *myopia, hypermetropia, presbyopia* and *astigmatism.*

Myopia is due to an abnormal elongation of the eye ball, and too great a degree of convexity of the lens. The rays of light are brought to a focus in front of the retina, and the images are indistinct and blurred (Fig. 116, 4). The eye is naturally accommodated for a near point, and objects near the eye are exactly focused, while those beyond the far point cannot be distinctly seen. This defect is remedied by wearing concave glasses. On the other hand, when the eye is short, and the lens flat, parallel rays are focused *behind* the retina; the eye is naturally accommodated for distant objects (Fig. 116, 3). This is called *hypermetropia,* and may be remedied by wearing convex glasses which converge the rays of light *Presbyopia* is an *error of refraction,* and must not be confounded with hypermetropia. It is the gradual loss of the power of accommodation which occurs with advanced age,

and is likewise remedied by the use of convex glasses. *Astigmatism*, first discovered by Airy, is due to a greater curvature of the eye in one plane than in another, so that vertical and horizontal lines crossing each other cannot be

Fig. 116.



focused at the same point, and the images are blurred and indistinct. It may be remedied by using glasses curved only in one direction—cylindrical glasses.

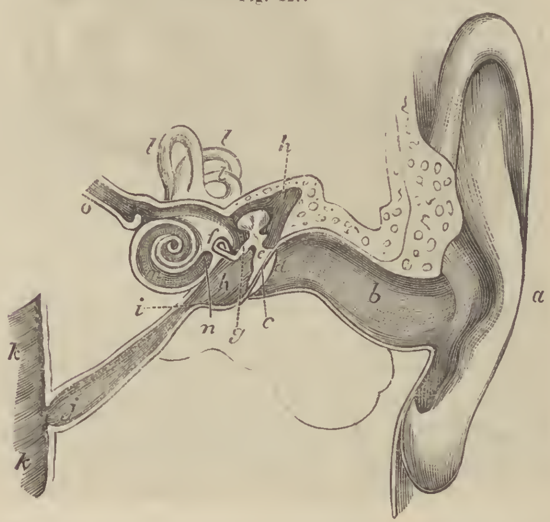
Daltonism, or color blindness, is also a defect of frequent cocurrence; many persons are wholly unable to distinguish between red, green and yellow. This would appear to arise from some defect in those elements of the retina which receive the impressions of these colors.

HEARING.

The ear is the organ of hearing, and is composed of three portions, the *external*, *middle* and *internal* ear.

The *external ear* consists of an expanded portion, the *pinna*, the *meatus auditorius externus*, and *auditory canal.* Its use is to collect the vibrations of the air, and conduct them to the membrana tympani, or drum, which separates the external from the middle ear. The canal contains some fine hairs at its outer part, and also a number of sebaceous glands throughout its whole extent, which secrete a waxy substance termed *cerumen.*

Fig. 117.



a, Pinna; *b*, external auditory passage; *c*, membrana tympani (section); *d*, insertion of membrana tympani in bony canal; *e*, insertion of malleus in membrana tympani; *f*, base of stapes, inserted in the fenestra ovalis; *g*, incus, joining stapes and malleus, and completing the chain of ossicles; *h*, cavity of the tympanum; *i*, Eustachian opening of tympanum; *j*, opening of Eustachian tube in the pharynx; *k*, posterior part of pharynx; *l*, semicircular canals; *m*, *n*, cochlea; *o*, trunk of auditory nerve.

The *middle ear* or *tympanum* is situated in the petrous portion of the temporal bone, between the membrana tympani externally, and the internal ear or labyrinth internally. It is filled with air, and communicates with the

pharynx through the Eustachian tube, which opens at the back part of the inferior meatus, (Fig 111). It also communicates posteriorly with air cavities in the mastoid process of the temporal bone, the *mastoid cells.* It is crossed by a chain of movable bones, which receive the impressions from the membrana tympani, and serve to

Fig. 118.

Interior of the osseous labyrinth. V. Vestibule, *av.* Aqueduct of the vestibule. *o.* Fovea hemielliptica. *r.* Fovea hemispherica. S. Semicircular canals. *s.* Superior. *p.* Posterior. *i.* Inferior. *a, a, a.* The ampullar extremity of each. C. Cochlea. *ac.* Aqueduct of the cochlea. *sv.* Osseous zone of the lamina spiralis, above which is the scala vestibuli, communicating with the vestibule. *st.* Scala tympani below the spiral lamina.

transmit them to the internal ear, upon which the auditory nerve is distributed. The bones of the ear are the *malleus, incus,* and *stapes;* the handle of the malleus is received between the inner and middle layers of the membrana tympani, and the stapes is implanted in the fenestra ovalis. The cavity of the tympanum and its chain of bones are lined with mucous membrane, continuous with the pharynx through the Eustachian tube, and covered with ciliated epithelium.

The *internal ear* or *labyrinth,* is the essential part of the organ of hearing, and consists of the vestibule, semi-

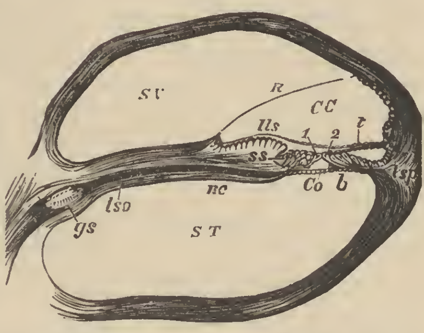
circular canals, and cochlea. It consists of a series of cavities hollowed out of the petrous portion of the temporal bone, communicating externally with the middle ear through the fenestra ovalis and fenestra rotunda, and internally with the cranial cavity through the meatus auditorius internus, which transmits the auditory nerve.

The *vestibule* is the central organ and middle cavity of the labyrinth. In its inner wall are several openings for the entrance of the branches of the auditory nerve; in its outer wall is the opening of the fenestra ovalis which receives the stapes; in its posterior and superior walls are the openings, five in number, of the semicircular canals; and in its anterior wall the opening into the cochlea. The *semicircular canals* are three arched bony canals which open at both ends into the vestibule, two of them first coalescing. One end of each, more dilated than the other, is called the ampulla.

The *cochlea* is situated in front of the vestibule, and is shaped like a snail shell. Its axis presents a conical column, the *modiolus*, around which winds a spiral canal, making about two and a half turns from the base to the apex. At the base there are *three* openings, the *vestibular opening*, the *fenestra rotunda* and the *aquæductus cochlea*. The spiral canal is divided into passages or scalæ, by the *lamina spiralis ossea* which consists of two laminæ of bone between which are canals for the entrance of the nervus cochlearis. One of these passages communicates with the vestibule, the *scala vestibuli;* the other with the tympanum, the *scala tympani.* Between these is a third space called the *scala media,* or canalis cochleæ (Fig. 119, CC) The lamina spiralis ends at the apex of the cochlea in a small hamulus, the inner and concave surface of which, when separated from the modiolus leaves a small aperture, the *helicotrema* through which the scalæ, separated in the rest of their extent, communicate. The lamina spiralis ossea extends only

part of the distance between the modiolus and the outer wall of the cochlea, and swells up at the outer end, forming the *limbus laminæ spiralis*, the border of which is grooved, the *sulcus spiralis*. From the inferior margin of this groove a membrane stretches across to the bony wall of the cochlea completing the lamina spiralis, called the *membrana basilaris*, the outer attachment of which forms a thick triangular structure the *ligamentum spirale*. From the upper margin of the *sulcus spiralis* stretches across another membrane which covers over the organ of Corti, the *membrana tectoria*, or *membrane of Corti*. Further inwards is another thin membrane, the *membrane of Reissner*, which stretches across and forms the scala media, or *canalis cochleæ*. The *organ of Corti* is situated upon the membrana basilaris. It consists of the rods of Corti, arranged in a series of arches formed by the internal and external rods roofing over the zona arcuata (Fig. 119. 1, 2.). They incline inwards towards each other, and each ends in a swelling termed the head, the convexity of one fitting into the concavity of the other like an articulation. It has been estimated that there are about 3000 of these pairs of rods or pillars from the base to the apex of the cochlea. On both sides of these rods are cylindrical epithelial cells, some of which are provided with cilia (cells of Corti.)

Fig. 119.



Section through one of the coils of the cochlea ST, scala tympani; SV, scala vestibuli; CC, scala media or canalis cochleæ; R, membrane of Reissner, with its single layer of nucleated flattened cells; *lls*, limbus laminæ spiralis; *ss*, sulcus spiralis; *gs*, ganglion spirale seated on *nc*, the nervus cochlearis, indicated by the black line; *lso*, lamina spiralis ossea; *t*, membrana tectoria of Corti; *b*, membrana basilaris; *Co*, organ of Corti; *lsp*, ligamentum spirale; 1, internal rod of Corti; 2, external rod of Corti.

Within the osseous labyrinth is contained the membran-

ous labyrinth, upon which is distributed the filaments of the auditory nerve. The membranous labyrinth is filled with a transparent fluid, called *endolymph* ; while between it and the osseous covering is a fluid called *perilymph*, so that the sonorous vibrations which reach the auditory nerve in these parts are conducted through fluid, to a membrane containing fluid. In the vestibular portion of the membranous labyrinth are two cavities; the upper and larger is named he *utriculus*, and the lower the *sacculus*. They are situated respectively in the *fovea hemielliptica* and the *fovea hemispherica* and contain small masses of calcareous matter, the *otoliths* (Fig. 118). The utricle communicates with the membranous semicircular canals and the saccule with the canalis cochleæ.

THE MECHANISM OF HEARING.—The *auditory nerve* as it enters the ear divides into two branches, one to the vestibule and the ampullæ of the semicircular canals, and the other to the cochlea. The branches of the cochlear nerve enter through openings at the base of the modiolus, and pass into canals between the plates of the lamina spiralis, in which they form a plexus containing ganglion cells (Fig. 119, *gs*), and terminate in the organ of Corti. The external ear favors the propagation of sound by collecting the sonorous undulations, and conducting them to the membrana tympani, and also by the resonance of the column of air contained in the auditory canal. The elevations and depressions of the pinna serve a useful purpose, for sonorous undulations from whatever direction they come, must fall perpendicularly upon the tangent of some one of them. Sonorous vibrations are conducted to the ear by three different media, the *air*, the *ossicles* of the ear, and the *fluid* of the labyrinth. The propagation of the sounds to the fluid, is made more perfect by reason of the ossicles being fixed in the middle of a tense vibrating membrane, with air on both sides, as the tympanum. Sounds are collected by the external ear and are transmitted to the membrana tympani. They

are here modified by the tense or lax state of this membrane, produced by the action of the laxator and tensor tympani muscles. The modified vibrations from the membrana tympani are thence conducted along the chain of bones to the fluid of the labyrinth, and through it transmitted to the auditory nerve, which receives the impressions, and conveys them to the sensorium. From various experiments which have been performed, it appears that tension of the membrana tympani is unfavorable generally to the propagation of sounds, especially those of a low pitch. This may be shown by making a continuous effort of expiration or of inspiration, while the mouth and nostrils are closed by the hand. The effort of expiration causes the air to be forced into the tympanum through the Eustachian tube, the membrana tympani is made to bulge out and become *tense*, and the hearing is indistinct. The effort of inspiration exhausts the air from the cavity of the tympanum, and the pressure from without causes the membrana tympani to bulge inwards and become tense, and is followed by temporary deafness.

The action of the chain of bones, as conductors, is enhanced by the presence of air in the cavity of the tympanum. It serves to isolate the bones so as to propagate the vibrations with concentrated intensity, and prevent the dispersion of sound. The air is supplied through the Eustachian tube, which communicates with the pharynx just behind the posterior nares. When persons are listening very intently, the mouth is usually partly open, in order to allow a free current of air to pass through the Eustachian tube.

The semicircular canals collect the sonorous undulations from the bones of the cranium and conduct them to the ampullæ and utriculus, where the auditory nerve is distributed. The cochlea is intended for the spreading out of the nerve fibres over a wide extent of surface, and for the perception of sounds by the solid parts and the walls of the labyrinth. The membranous labyrinth of the vestibule and semicircu-

lar canals is suspended free in the perilymph and receives the sounds through the medium of that fluid, while on the other hand the lamina spiralis upon which the cochlear nerve is expanded is continuous with the solid walls of the cochlea from which it receives impressions directly. The function of the rods of Corti is probably to receive impressions of various notes and tones, and communicate them to the brain through the filaments with which the rods are connected. The *intensity* of a sound is due to the length of the vibrations, the *pitch* to the number in a second, and the *quality* to the number of secondary notes. The power of determining the *direction* and *distance* of sounds is acquired by experience.

Any irritation or excitement of the auditory nerve, as congestion, cerebral disease, etc., may give rise to ringing or buzzing sounds in the ears. These are called *subjective sounds,* because they are produced by internal causes.

The sense of hearing varies much in different individuals, and in the same individual at different times; some will discern the most delicate sounds without the least difficulty, whilst others are wholly incapable of receiving similar impressions. Hearing may be impaired by a preternaturally dry state of the membrana tympani, or the partial closure of the external meatus by collections of wax, particles of dust, etc. In some of the lower animals, the sense of hearing is very acute.

SENSE OF TASTE.

The principal organs of the sense of taste, are the tongue and fauces. The conditions necessary are the presence of special nerves to convey the impressions received, and the excitation of these nerves by sapid matters in a state of solution. The nerves are the lingual branch of the fifth, and the glosso-pharyngeal (p. 333). The tongue is a muscular organ, covered with mucous membrane and presents numerous papillæ. These have been already described (p. 107). The muscles are divided into *intrinsic,* or those that form the

greater part of the substance of the tongue, as the linguales; and *extrinsic* or those which attach it to surrounding parts, as the hyo-glossus, genio-hyoglossus, stylo-glossus, etc. The epithelium of the tongue is of the squamous variety,

Fig. 120.

The tongue with its papillæ and nerves. 1, Hypoglossal nerve. 2, Lingual branch of the trifacial. 3, Lingual branch of the glosso-pharyngeal nerve. 4, Chorda tympani. 8, Sub-maxillary ganglion. 11, Anastomoses of the lingual with the hypoglossal uerve. 12, Facial nerve. 13 Mucous membrane detached and thrown upwards; the circumvallate papillæ are seen behind. (Hirschfeld.)

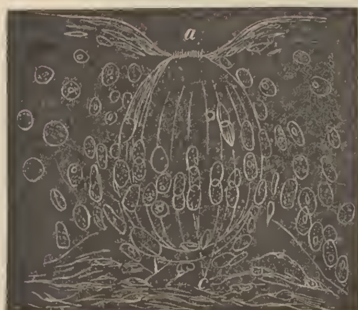
and covers every part of the surface, but is thinner in some parts than others, as on the fungiform papillæ. Peculiar structures, known as *taste buds* or *taste goblets*, have been discovered in the circumvallate papillæ and on the posterior surface of the epiglottis. They are oval in shape, and consist of narrow fusiform *gustatory* cells surrounded by a layer of broader fusiform or *encasing* cells (Fig. 121). A depression exists in the epithelium over the goblet, and the gustatory cells present hair like processes which resemble cilia. These bodies are found side by side in considerable numbers, and are believed to be gustatory in function, but as yet no nerves have been traced into them.

The fauces, uvula, tonsils, and upper part of the pharynx, all of which are supplied with branches of the glosso-

pharyngeal nerve,are endowed with the sense of taste. In most persons the sense of taste is most acute in the tip and edges of the tongue; while in the middle of the dorsum it is feeble.

The tongue also possesses an accurate sense of touch, and is capable of receiving impressions of heat or cold, pain, mechanical pressure, and the form of surfaces. Its common sensibility may be impaired or lost, and the sense of taste still continue. The nerve fibres for these two sensations, although found in the same papillæ, are distinct, just as the olfactory nerves and the nerves of common sensation in the nose are distinct. The senses of smell and taste are closely associated, for if the former be impaired or lost as in disease, the latter is rendered less acute. Taste appears to be governed to some extent by the same principles as that of sight; viz. that those tastes which are opposite or complementary, render each other more distinct, as sweet and bitter acid and alkaline, etc. The sense of taste is very delicate, though not to be compared with the sense of smell. It may be rendered less distinct in regard to any substance by constant contact with it, in the same way as the eye becomes fatigued with the constant perception of a single color. *Subjective* sensations of taste frequently occur in diseased conditions of the nerves of taste, or their associate nerves.

Fig. 121.



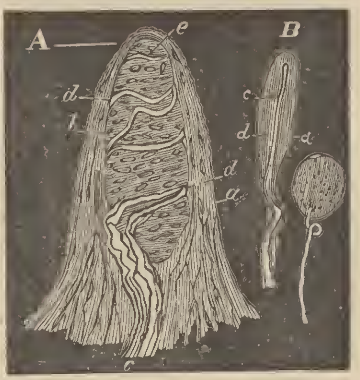
Taste goblet: a, depression in the epithelium over the goblet; b, nuclei of encasing cells; c, two nuclei of the gustatory cells.

SENSE OF TOUCH.

The sense of touch has a wider range than the other senses, and varies greatly in the different parts of the body. It is greatest at the extremities of the fingers, lips and

tongue, and least in the integument of the trunk, arms and thighs (p. 124). There are no special nerves of the sense of touch; they are simply the nerves of common sensation supplied to all parts of the body, and hence it is that all parts are endowed with this sense. Touch is simply an exaltation of common sensation. Some are of the opinion, that common sensation and tactile sensation are communicated to the sensorium through different sets of nerves. Those parts of the body in which the sense of touch is most acute are abundantly provided with papillæ, which increase the extent of surface for nerve distribution. These papillæ vary in size from $\frac{1}{100}$ to $\frac{1}{250}$ of an inch (.25 to .1 mm). The nerves distributed to them are destitute of the white substance of Schwann, and appear to terminate in oval-shaped bodies, formed of connective tissue named tactile corpuscles (Fig. 122, A). In some of the papillæ, as those of the lips, tongue, palate and integument of the glans penis, the nerves terminate in small round bodies, $\frac{1}{600}$ of an inch (42 mmm,) in diameter, the end bulbs of Krause (Fig. 122,B). In the palms of the hands, points of the fingers and soles of the feet, the papillæ are arranged in rows, and form ridges and furrows which may be seen with the naked eye (p. 116). The sense of touch is peculiar from being widely distributed; even the eyelashes, hair (near the root), nails and teeth exhibit this sense in a manner peculiar to themselves. The integument is endowed not only with the sense of touch, *per se*, but also with the sense of *pressure*, *temperature* and *pain*; the latter being a highly exalted sensation of the three former.

Fig. 122.



A. Tactile corpuscle; B, end-bulbs of Krause (see page 287).

Some parts of the body are sensitive to tickling as the axillæ and soles of the feet, but are comparatively blunt in regard to the special sense of touch.

The sense of touch enables the mind to become acquainted with the condition of bodies, whether hot or cold, rough or smooth, hard or soft, wet or dry, and their size, form, etc. The organs by which touch is chiefly exercised, are the hands, and especially the points of the fingers, which are abundantly provided with papillæ for that purpose. The variation in sensibility in different parts may be determined by the aid of a pair of compasses. Thus the two points of a pair of compasses may be separately distinguished by the point of the finger when only about one-third to one-half a line apart, while they require to be twenty to thirty lines apart, to be separately felt on the integument of the spine, arm, thigh, sacral or gluteal region. The two points are felt separately on the tip of the tongue when $\frac{1}{24}$ of an inch apart, on the middle of the dorsum of the tongue, $\frac{1}{3}$ of an inch, on the lip $\frac{1}{6}$ of an inch, and on the tip of the nose, when $\frac{1}{4}$ of an inch apart. The *æsthesiometer*, an instrument for determining the relative sensibility of the arms or legs in paralysis, is constructed on this principle. The sense of touch may be very much increased by constant practice, as is seen in the case of the blind, who acquire a remarkable facility for reading raised letters, by the aid of the fingers.

The sense of *pressure* is produced by weight or tension, and is intensified according to the increase of the weight or tension. In lifting a body we judge of its weight partly by the pressure on the hands, and partly by the amount of muscular force used in raising it. The latter is called the *muscular sense* (p. 309). These two faculties give us the power of discerning the relative weight of bodies. We have also the power of estimating beforehand, and regulating the amount of muscular force required in lifting heavy bodies. If we attempt to lift an object which we have conceived to be heavier than it really is, we are liable to be

overturned by the muscular effort unnecessarily put forth to overcome the supposed resistance.

The sense of *temperature* is distinct from that of touch, and may remain unimpaired when the latter is for the time in abeyance, as when a nerve is pressed upon or partly injured. The sensations of temperature, however, are very deceptive, and cannot be relied upon; as *e.g.* in the cold stage of disease, the patient feels excessively cold, while the thermometer shows that the temperature is over 100°F. Again, if one hand be put in cold water, and the other in water at a temperature of 110°F., and both are then immersed in water at 80°F., it will feel warm to the hand previously in the cold water, and cold to the other. In examining patients in cases of fever or inflammation, in regard to the heat of the skin, no reliance can be placed on the sensation of heat communicated to the hand, and therefore the thermometer should always be used. Some parts of the body will bear a higher degree of temperature than others, *e.g.*, the hand will resist a temperature which would be intolerable to the body. Only ordinary temperatures can be discriminated, viz., from 50° to 120°F.; very high or very low temperatures produce a burning sensation. *Subjective sensations* of touch, arising from some internal causes, are of frequent occurrence, as heat, cold, rigor, neuralgic pains, itching, formication, etc.

CHAPTER XV.

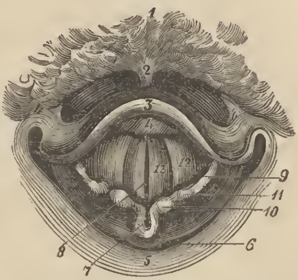
VOICE.

The *Larynx* is the organ of voice, and is situated at the upper part of the air passage, between the trachea and base of the tongue, at the upper and anterior part of the neck. It is narrow and cylindrical below, but is wide and triangular at the upper part. It is composed of cartilages, which are held together by ligaments, and acted upon by numerous muscles. It is lined by mucous membrane, covered with columnar ciliated epithelium below the superior vocal cords and the upper part in front; the rest of its extent is covered with squamous epithelium. The upper part of the larynx presents a triangular-shaped orifice, wider in front than behind—the *glottis.* This opening is guarded by the *epiglottis,* which is situated in front, between the opening and the root of the tongue. The epiglottis closes the orifice during the passage of food or fluids, and prevents their passage into the larynx. Within the cavity of the larynx, on each lateral wall, may be seen two elevated bands, the *superior* and *inferior vocal cords,* separated by an elliptical depression—the *ventricle of the larynx* (Fig. 111 *f,*) p. 341. Of the two vocal cords, the inferior consists of a band of yellow elastic tissue, covered by mucous membrane, and is called the *true vocal cord;* while the superior, which is formed entirely by a folding of the mucous membrane, is called the *false vocal cord,* because it is not concerned in the production of the voice. It is in the larynx that the sounds are originally produced; but they may be modified during and after their production by the tongue, palate,

teeth, lips, etc., constituting, in man, the faculty of speech.

The interval between the true vocal cords in the median line is called the *rima glottidis*, or chink of the glottis, the narrowing or widening of which, and the tension or laxity of the cords, produce those variations of sound which are characteristic of the human voice. The narrower the opening and the tenser the cords, *cœteris paribus*, the higher the pitch of the note. The tension of the vocal cords and the size of the aperture, are regulated by muscles which are situated in the larynx. It has been proved by observation on the living subject, as well as by experiments on the larynx of the dead body, that the sound of the voice is caused by the vibration produced by the currents of expired air passing over the margins of the true vocal cords. For example, if a free opening be made in the trachea, the sound of the voice ceases, but returns as soon as the opening is closed. Again, distinct vocal sounds may be produced in the dead subject by forcing a current of air through the larynx, and this will occur even when all the structures above the vocal cords are removed.

Fig. 123.



Glottis seen with the laryngoscope during the emission of high-pitched sounds.—1, 2, base of the tongue; 3, 4, epiglottis; 5, 6, pharynx; 7, arytenoid cartilages; 8, opening between the true vocal cords; 9, aryteno-epiglottidean folds; 10, cartilage of Santorini; 11, cuneiform cartilage; 12, superior vocal cords; 13, inferior vocal cords.—(Le Bon.)

The essential parts of the larynx are the thyroid cartilage, the cricoid cartilage, the two arytenoid cartilages and the true vocal chords. The latter are attached behind to the front portion of the base of the arytenoid cartilages, and in front to the depression between the two alæ of the thyroid cartilage, so that all movements of the arytenoid cartilages produce an effect on the vocal cords. Movements of the cricoid cartilage also produce an effect on the vocal cords indirectly, since the arytenoid cartilages rest upon its poste-

rior part. Those muscles which act upon the arytenoid cartilages either directly or indirectly, nine in number, are called the *intrinsic* muscles of the larynx, viz.: two *crico-thyroid* muscles, two *thyro-arytenoid*, two *posterior crico-arytenoid*, two *lateral crico-arytenoid*, and one *arytenoid* muscle. The crico-thyroid, produce tension and elongation of the vocal cords by drawing downwards and forwards the thyroid cartilage over the cricoid. The thyro-arytenoid draw the arytenoid cartilages forwards towards the thyroid and relax the vocal cords. The posterior crico-arytenoid rotate the base of the arytenoid cartilages outwards and backwards, separate the vocal cords and open the glottis. The lateral crico-arytenoid rotate the arytenoid cartilages inwards and close the glottis. The arytenoid muscle approximates the arytenoid cartilages and closes the glottis, especially at its posterior post. The nerves which govern these actions are the branches of the pneumogastric and spinal accessory (p. 333).

The combined action of the muscles places the vocal cords in the various positions necessary for breathing and the production of sounds, as in singing, speaking, etc. In ordinary tranquil breathing the opening of the glottis is wide and triangular, and becomes a little narrower at each expiration. In the production of sound it is narrowed, and the tension of the vocal cords increased. In the production of higher notes the vocal cords are more closely approximated and rendered more tense (Fig. 123). In the space between the arytenoid cartilages at the posterior part of the glottis, no regular vocal sound is produced, nothing more than a mere rustling or gurgling sound. The tone of the voice is somewhat lowered by the action of the *epiglottis* when it partially covers the cavity of the larynx. The ventricles of the larynx are for the purpose of affording free space for the vibrations of the vocal cords.

The modes of sequence of the notes of the voice are *three* in number; 1st. The *monotonous*, as in ordinary speaking,

with occasional intonation for the sake of accent; 2nd, the *transitional*, from high to low notes and *vice versa* without intervals; such as in crying in man, and the howling of animals, and 3rd, the *musical*, in which each note has a determinate number of vibrations.

The *compass of the voice* varies in different individuals from one to three octaves, and some singers may even exceed three octaves. Before puberty, the pitch of the male and female voice is nearly the same, the male voice being a little louder; but at this period the larynx of the male undergoes certain changes, during which the voice is said to "*crack*," and the pitch falls about one octave. This change does not take place in eunuchs, and they retain the puerile character of the voice. The different pitch of the male and female voice depends on the different length of the vocal cords in the two sexes, viz.: as three to two respectively. The lowest note of the female voice is an octave higher than the lowest note of the male voice, and the compass of the two is about four octaves. There are two kinds of male voice, the bass and tenor, and also two kinds of female voice, the contralto and soprano, all differing from each other in tone. The bass voice reaches lower than the tenor, and its strength lies in the low notes; while the soprano reaches the highest in the scale. The essential distinction between the different voices, however, consists in the tone which distinguishes them when they are singing the same note. Most persons have the power of modulating their voices through a double series of notes of different characters, viz.; the *chest notes* or the notes of the natural voice, and the *falsetto notes.* The former are produced by the ordinary vibrations of the vocal cords and are much stronger; the latter, in all probability, by the vibration of only the inner border of the vocal cords, and are of a flute-like character.

The voice is principally used in man in the formation of speech. The tone of the speech depends much upon the

state of the chordæ vocales, and the development of the larynx; but *articulation*, or modification of the sounds, is effected by the lips, teeth, mouth, tongue, fauces and nose. Articulate sounds, or the sounds produced in speech, are commonly divided into *vowels* and *consonants*; the former are sounded by the larynx, while the latter are produced by the interruption of the current of air above the larynx. All vowel sounds can be expressed in a whisper, without vocal tone—*mutely*. During the production of the vowel sounds the posterior nares are closed, and no air issues through the nose. The consonants cannot be sounded except *consonantly* with a vowel, hence the name. They are divided into *labial, dental* or *guttural*, according to the interruption to the current of air required in their formation, as by the lips, teeth, palate or pharynx. They may also be classified according to the character of the movements which give rise to them, as *explosives*, as *p, b, t, d*, etc., *aspirates*, as *f, v, s, l. z*, etc., *resonants*, as *m, n, ng*, etc., and *vibratory* as *r*.

Ventriloquism appears to consist in the varied modification of the sounds produced in the larynx, so as to imitate the voice as heard from a distance. It is accomplished by taking a full inspiration, then keeping the muscles of the neck and chest fixed, and speaking with the mouth almost closed and the lips motionless, while air is slowly expired through a narrow glottis, care being taken that none of the expired air passes through the nose. The attention of the audience is at the same time generally directed to that part of the room from which the sound is expected, a circumstance which adds materially to the success of the performance.

Stammering, in most instances, is an affection of the nervous system, and not of the articulating organs. It consists in an imperfect power of co-ordinating the muscles of speech, associated with a spasmodic action of certain muscles concerned in the formation of the voice. Some stammer only on attempting to articulate certain letters; others

do so at every attempt to speak. It is much increased by any mental excitement, surprise, etc. Females seldom stammer, although more subject to nervous disorders generally than males. The cure of stammering is best effected by training the muscles in the production of the sounds most easily formed, and thence proceeding to the most difficult; to avoid all causes of excitement to the patient, and prevent him from thinking about his condition as much as possible Some have recommended the use of pebbles in the mouth, or small pieces of ivory; but it is very doubtful whether or not these can be of any great service.

CHAPTER XVI.

REPRODUCTION.

The process of reproduction comprises the several provisions made for the multiplication of individuals and the propagation of the species. There are three modes by which the multiplication of individuals takes place in the lower orders of organized beings, while in the higher forms it is restricted to one of these types.

The *first* and simplest *mode* consists in the division of the being into two, each of these again subdividing into two others, and so on. This is *multiplication by subdivision*; or *fissiparous multiplication* (Fig. 124). It is seen in the lowest plants, as in the cells of fungi and lichens, and also in cartilage and other cells of the human body. The amœba also furnishes a good example of this mode of reproduction. It throws out a large process in a certain direction, becomes contracted at or near the middle, and divides into two or more parts, each containing a portion of the original nucleus. Some organizations, as the polyp, when divided artificially

into segments, have the power of developing into a perfect form from each segment.

The *second mode* takes place by a process of *gemmation*, or budding from the parent stalk. These buds, which consist of a mass of cells, are at first entirely nourished by the parent stalk, but gradually become less dependent, and at

Fig. 124.

A cell undergoing the process of multiplication by subdivision ; a, original cell ; b, cell becoming oval ; c, undergoing hour-glass contraction ; d, division of the cell into two.

Fig. 125.

Amœba ; in the centre is seen the nucleus and surrounding it a number of vacuoles and granules

last detach themselves and maintain a separate existence. This is termed *multiplication by gemmation* or *gemmiparous multiplication*. The hydra affords a good example of this variety. The first change which is observed is a slight elevation on the surface, which assumes a globular form ; a cavity is then formed in the interior, which communicates with the parent. After a time this channel of commnnication closes, the newly-formed polyp drops off, and a new creature is formed. The joints of the common tape-worm multiply in this manner. This process is also common among the Bryozoa, and leads to the formation of colonies.

The *third mode* is called *true generation*, and consists in the union of the contents of two different cells, the *sperm cell* and the *germ cell*, from which is produced a new being differing from both. The simplest form of this process is seen in the Algæ in *conjugation*. At first the opposite cells of two filaments form a process on the sides next each other ; these at length meet and fuse, and the contents of the two cells become mixed and form a new body termed a *spore* or sporangium, from which the new plant is formed.

In the higher plants and animals distinct organs are set apart for the formation of the sperm cells and germ cells; the former are produced by the male organs of generation, the latter by the female. Through the action of the contents of the sperm cell the ovum becomes impregnated, and an embryo is formed from which the adult animal is gradually developed. In some instances, however, as in the class of insects, several distinct changes or *metamorphoses* are passed through before the animal is fully developed, as the larva, chrysalis, and perfect animal. In other instances the embryo, instead of being developed into the perfect animal, only attains a sort of larval condition, and there may be several series of these imperfect or larval forms, each larva producing other larvæ, until at last they give rise to perfect forms, which propagate only by the production of ova. This is called by Prof. Owen *metagenesis.*

Action of the Male.—The male furnishes the spermatic fluid or sperm, which is secreted by the *testes.* This fluid contains the sperm cells in which are developed the *spermatozoa;* also an albuminous substance, various salts and an animal substance resembling fibrin termed spermatine. The sperm cells are large spherical vesicles, in which are contained from two to nine smaller cells or nuclei, in each of which is found a spermatozoon. The spermatozoa are the essential elements of the spermatic fluid, and are set free by the breaking down of the sperm cells (Fig. 126 ,a). They are transparent filamentous bodies, about $\frac{1}{600}$ of an inch (42 mmm.) in length, and from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch (5 to 25 mmm.) in thickness, being thicker at the anterior extremity or head than the posterior or tail. Their movement is accomplished by the constant vibration of the tail;

Fig. 126.

a, Human spermatozoa magnified 350 diameters; b, sperm cell containing the spermatozoon coiled up within it; c, cell elongated by the partial uncoiling of the spermatozoon.

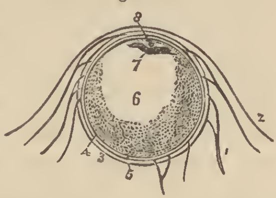
they are said to move at the rate of one inch in seven and one-half minutes. Their movements may be suspended, and their power of impregnation destroyed by profuse leucorrhœal discharges or acrid secretions of the vagina, and by the action of solutions which act chemically upon them, as solution of silver nitrate, zinc sulphate, zinc chloride, etc. In the female organs of generation the movements continue longer than in any other situation.

In the act of coition the seminal fluid is deposited in the vagina, and the spermatozoa make their way into the uterus and meet the ovum at or soon after its discharge from the ovary. One or more are supposed to pierce the vitelline membrane and pass into the interior of the ovum or germ cell, and unite with it, after which they disappear. It is also supposed by some that they enter through a small opening or *micropyle*, and by others that they perforate the vitelline membrane. The fecundation of the egg may take place either in the uterus, Fallopian tube, or ovary, in each of which situations spermatozoa have been found after coition. The high degree of nervous excitement which attends the act of coition, is followed by a corresponding amount of depression, and the too frequent repetition of it is very injurious to the general health. This is still more the case with that *solitary vice*, which it is to be feared is practised by too many youths. Nothing is more certain to reduce the powers both of *body* and *mind*, than excesses in this respect.

Action of the Female.—The essential parts of the female organs of generation, and counterpart of the testes, are the *ovaries*, in which the ova are developed. Each ovary is about an inch and a half long, three-fourths of an inch wide, and half an inch in thickness, and is attached to the uterus by the ligament of the ovary, and to the Fallopian tube by one of the fimbriæ, the rest of the surface being covered with columnar epithelium, beneath which is the proper covering of the organ—the *tunica albuginea*—

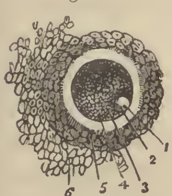
which is a dense, firm membrane, enclosing the parenchyma or *stroma*. The stroma consists of two parts, an external or *cortical* portion, whitish in color, and an internal *medullary* or vascular zone, reddish in color, and consisting of vessels elastic fibres and connective tissue among which are a number of non-striated muscular fibres. The external portion consists of a network of connective tissue in which the Graafian vesicles are formed. There are also a large number of nuclei in the interstices. The Graafian vesicles or ovisacs, exist in very large numbers from the earliest periods of life, and in all stages of development. They vary in size from a pin's head to a pea, and contain the ova. Each *Graafian vesicle* consists of an *external vascular*, and an *internal serous coat*, named the *ovicapsule*. The internal coat is lined internally by a layer of nucleated cells, called the *membrana granulosa*, and within this is situated the *ovum*. The cells of the membrana granulosa are accumulated in large numbers around the ovum, forming a granular zone, the *cumulus, discus proligerus, retinacula* or *chalaza*. The cavity of the Graafian vesicle is filled with an albuminous fluid in which granules float.

Fig. 127.



Graafian vesicle: 1, stroma; 2, peritoneum; 3 and 4, coats of the Graafian vesicle; 5, membrana granulosa; 6, fluid of the Graafian vesicle; 7, discus proligerus; 8, ovum.

Fig. 128.



Ovum: 1, germinal spot; 2, germinal vesicle; 3, yolk; 4, zona pellucida; 5, discus proligerus; 6, adherent granules or cells.

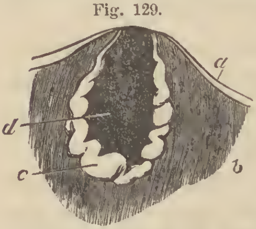
The *ovum* is a small spherical body, about $\frac{1}{120}$ of an inch (.2 mm) in diameter. It consists externally of a transparent envelope, the *zona pellucida* or *vitelline membrane*, and within this is the *yolk* or *vitellus*. Imbedded in the substance of the yolk is a small vesicular body, the *germinal vesicle*, and within the germinal vesicle is the *germinal spot*. The latter is about $\frac{1}{3000}$ of an inch (8mmm.) in diameter. The vitelline membrane is a colorless transparent membrane, which appears as a bright

ring with a dark border externally and internally, and is about $\frac{1}{2500}$ of an inch (10 mmm.) in thickness. The yolk consists of granular protoplasm, the smaller granules resembling pigment, and the larger, more numerous at the periphery, fat globules. The germinal vesicle contains a watery fluid in which are found a few granules.

At the approach of the menstrual period, one (or probably more) of the Graafian vesicles enlarges, approaches the surface of the ovary, and when mature, forms a small projection on the surface. It finally bursts, the ovum escapes, and is caught by the fimbriated extremity of the Fallopian tube, and by it conducted to the uterus.

Corpus Luteum.—When the Graafian vesicle has matured, and is about to burst and expel the ovum, it becomes highly vascular and opaque, and its coats are thickened by a glutinous looking substance. As the ovum escapes, it leaves behind it the external vascular and the internal serous coats of the Graafian vesicle, the cavity of which is immediately filled with a bloody fluid which soon coagulates, and the cicatrix presents a yellowish appearance; hence it has been called the *corpus luteum* (Fig. 129). After a short time the coagulum contracts, and the membranes become convoluted and hypertrophied, so that when the corpus luteum is divided transversely, about three weeks after its formation, it is seen to consist of a central firm coagulum surrounded by a convoluted wall of a reddish yellow color.

Fig. 129.



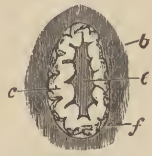
Corpus luteum, natural size, eight days after conception: *a*, external coat of the ovary; *b*, stroma of the ovary; *c*, convoluted wall of the Graafian follicle; *d*, clot of blood.

Corpora lutea are divided into *true* and *false*; the former are found only when conception has taken place; the latter are met with in the unimpregnated state. They are both produced in the same way, and for the first three weeks there is no distinction between them; but the true corpus luteum becomes

larger and remains longer than the false, in consequence of the increased vascularity of the parts after impregnation.

At the end of the third week they each measure about one-half or three-fourths of an inch in diameter. After this the false corpus luteum begins to diminish, and entirely disappears in the course of about two months, while the true increases in size, until about the fourth or fifth month, and then gradually declines until after parturition, when it rapidly disappears.

Fig. 130.



Corpus luteum, natural size, at the fith month of pregnancy ; *b*, stroma of the ovary ; *c*, convoluted wall of the Graafian follicle ; *e*, decolorized clot ; *f*, fibrous envelope of the corpus luteum.

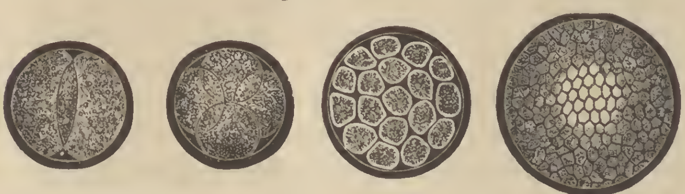
Action of the Oviducts.—In the human subject the oviducts commence by a wide fringed expansion—the fimbriated extremity of the Fallopian tubes. The ovum, in passing through the Fallopian tube to the uterus, absorbs a certain quantity of fluid, increases in size, and if impregnated soon presents a number of minute villi on its surface which give it a *shaggy* appearance. This is called the chorion.

In fowls, as the ovum leaves the ovary it enters the oviduct, and in passing the first portion, which is about two inches in length, it absorbs fluid and becomes more flexible and yielding. In the second portion, which is about nine inches in length, the mucous membrane is thick and glandular. In the upper part, it secretes a viscid fluid which surrounds the yolk and forms a gelatinous deposit around the vitelline membrane, and from the rotation given to the egg by the oviduct the two ends become twisted in opposite directions from the poles of the egg and form the *chalazæ.* The membrane which connects the chalazæ, is called the *chalaziferous membrane.* In the rest of this portion, an albuminous secretion is poured out to form the *albumen* or white of the egg. In the third division, which is about three inches in length, a material is poured out which condenses and forms three fibrous membranes, an *internal, middle* and

external. The egg then passes into the fourth division, which is about two inches long. This pours out a secretion containing calcareous matter, which is deposited in the meshes of the external membrane of the egg, forming the shell. After the expulsion of the egg, evaporation of some of the watery ingredients takes place through the pores of the shell, its place being filled with air. The air cavity is situated between the internal and middle membranes, at the large end of the egg. The vitellus is the essential part of the egg, the white simply contributing to the nourishment of the chick until it leaves the shell, and the membranes and shell affording the protective coverings.

Development of the Ovum.—After the ovum is impregnated a remarkable change takes place, which is known as the spontaneous division or *segmentation* of the vitellus. A furrow first shows itself surrounding the vitellus in a vertical direction, which gradually becomes deeper until it

Fig's. 131-4.

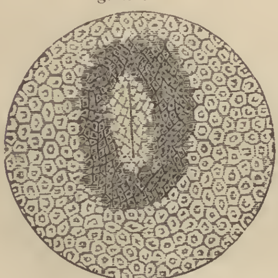


has divided into two portions. Each of these portions is again subdivided into two, and the four segments thus produced are divided into sixteen, and sixteen into sixty-four, and so on, until the whole mass has assumed a *mulberry appearance*, and is finally converted into "vitelline spheres" or "true animal cells," which adhering together, form the *blastodermic membrane.* These cells are also sometimes called the *primordial* or *primitive* cells, or *germinal vesicles.* The albuminous matter liquefies, and gradually passes by osmosis through the vitelline membrane into the interior of the egg. The blastodermic membrane then divides into two layers, the *external blastodermic, serous* or

animal layer, and the *internal blastodermic, mucous* or *vegetative layer*, both of which are composed of cells. The former produces the spinal column and organs of animal life; the latter the alimentary canal and organs of vegetative life. Up to this stage, the process is the same in all animals, birds, fishes, reptiles and mammalia.

The simplest form of development is seen in the egg of the *frog*. The egg, when discharged from the body and fecundated, is deposited in the water, surrounded by a layer of albuminous matter, and is freely exposed to the light and heat of the sun. The first sign of organization is the thickening and condensation of the external blastodermic membrane in one part, forming an elongated oval spot with opaque edges. This is called the *embryonic spot*. Enclosed

Fig. 135.



The impregnated ovum showing the embryonic spot, area pellucida and primitive trace.

Fig. 136.

Commencing formation of the embryo; a, external blastodermic layer; b, vitellus; c, embryo.

within this is a narrow transparent space, the *area pellucida*, in the centre of which is a longitudinal line, the *primitive trace*. On each side of the primitive trace in the area pellucida, the blastodermic membrane rises up in two plates, called the *dorsal plates*, which at last meet and enclose a foramen, the *spinal canal*, in which nervous matter is deposited to form the spinal cord, being enlarged anteriorly to accommodate the brain. At the same time the external blastodermic membrane grows outwards and downwards, to form the abdominal walls which embrace the internal blastodermic membrane and the fluid in its cavity. Beneath

the spinal canal is formed a cartilaginous cord, which is called the *chorda dorsalis*, from which the vertebræ are subsequently developed. As the whole mass grows rapidly, the head becomes thick and voluminous, while the tail begins to project backwards, and the embryo assumes an elongated form. The internal blastodermic layer forms the alimentary canal, the mouth and anus being developed by atrophy and perforation of the external layer of the blastodermic membrane at these points respectively. The young tadpole then ruptures the vitelline membrane and escapes, after which the extremities are developed by a process of budding or sprouting, and when fully formed, the tail atrophies and disappears. The animal at first breathes by gills; but these are subsequently replaced by the lungs.

Fig. 137.

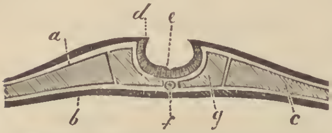


Diagram of a section of the embryo showing the formation of the spine; a, epiblast: b, hypoblast; c, mesoblast; d, margin of the lamina dorsalis; e, medullary groove; f, chorda dorsalis or notochord; g, primitive or protovertebra.

In the development of the chick which has been studied very carefully by various observers, the blastodermic membrane, or *blastoderm* divides into three layers, the two layers already referred to in the frog, and an "intermediate layer" or *mesoblast*. These three layers are designated by some, the *epiblast*, *mesoblast* or middle layer, and the *hypoblast*. The epiblast forms the epidermis and appendages, cerebro-spinal nerve centres, sensorial epithelium of the nose, eye, ear etc., and the epithelium of the mouth and salivary glands. From the mesoblast is formed the tissues of the body, connective, muscular and nervous tissues, vascular and genito-urinary systems, and digestive canal except its epithelium; and from the hypoblast is developed the epithelium of the alimentary canal and the ducts that open into it, and also the parenchyma of the glands, as the liver and pancreas. In the egg of the fowl, a whitish circular spot is seen, about $\frac{1}{5}$ of an inch (5 mm) in diameter, immediately beneath the vitelline membrane, the *cicatricula*, in the centre of which

is the germinal vesicle. When the egg is fecundated, segmentation begins in the cicatricula in the manner already described, until the blastoderm comes to occupy the place of the cicatricula. It then separates into the three layers above mentioned, in which certain prominences and foldings take place which mark out the commencing development of the different parts of the embryo, as the "headfold," "tailfold," etc., (Fig. 138.) On each side of the primitive trace (Fig. 135), the epiblast rises up to form the dorsal plates (laminæ dorsales), which soon meet and close in the spinal or medullary groove, and form a canal for the reception of the spinal cord and brain (Fig. 137, d). Beneath this canal in the mesoblast is formed the *chorda dorsalis* or notochord, which ultimately becomes the spinal column; on each side of the chorda dorsalis, a longitudinal thickening of the mesoblast takes place from which is formed the primitive vertebræ (protovertebræ). These structures form the bases out of which the spinal column and muscles are afterwards developed. On the outer side of the primitive, or protovertebræ, the mesoblast splits into two laminæ, one joins the epiblast (somatopleure) and forms the parietes of the trunk, and the other joins the hypoblast (splanchnopleure) and forms the alimentary canal and other parts. The general cavity of the body is formed by downward foldings of the blastoderm, somewhat resembling the formation of the nervous canal (Fig. 138). These downward foldings are called the *visceral plates.* In the frog these plates close in the whole of the vitellus.

In the chick, fish, etc., the internal blastodermic membrane is divided into two parts by a constriction, one of which forms the intestinal canal, while the other, remaining outside, forms the *umbilical vesicle,* which is surrounded by a portion of the external blastodermic membrane, and is gradually atrophied as development proceeds.

In the *human embryo* the umbilical vesicle becomes more completely separated, and forms a cord by its constriction,

at the distal extremity of which is situated the vesicle, which contains a clear transparent fluid (Fig. 139, g). The umbilical vesicle may continue until the end of the third month, after which it gradually disappears in the advancing development of the adjacent parts (Fig. 141).

FORMATION OF THE AMNION AND ALLANTOIS.—These are two accessory organs which belong to the higher order of animals, and their development has been carefully studied in the chick. The amnion is formed from the external layer of the blastodermic membrane, and the allantois from the internal; the former encloses a cavity or sac containing fluid in which the fœtus floats; the latter is a vascular structure destined to bring the blood of the embryo to the

Fig. 138 Fig. 139.

Diagram of the formation of the amnion and allantois:—*a*, vitelline membrane covered with the villi of the chorion; *b*, folds of the amnion surrounding the embryo; *c*, point of meeting of amniotic folds; *d*, outer layer of the amniotic fold; *e*, inner do.; *f*, amniotic cavity; *g*, umbilical vesicle; *h*, allantois; *i*, cavity of the intestine; *b′*, space between the two layers of the amnion; *o*, situation of the heart and vessels.

external sources of nutrition and atmospheric influence. These are not necessary to the development of the egg of the frog and fish, since absorption can readily take place through the vitelline membrane, from the media by which they are surrounded.

The *amnion* is first formed; this takes place by foldings of the external blastodermic membrane, which pass upwards from the abdominal surface on all sides of the embryo, until they meet and fuse at a point over the back which is called

the *amniotic umbilicus* (Fig. 138, *c*). Atrophy and separation then take place at this point, the inner layer of the fold forming the amnion; the outer, blending with the vitelline membrane, and forming the external investing membrane of the ovum. A shut sac is thus formed between the amnion and the fœtus called the amniotic cavity, which is filled with a clear fluid—the *liquor amnii* (Fig. 139, *f*).

About this time the *allantois* commences as a prolongation or diverticulum from the posterior part of the intestinal canal, and follows the course of the amniotic fold which preceded it, lying between its two layers (Fig. 139, h). It gradually increases in size until it covers the body of the embryo, together with the amnion; it then meets and fuses over the back as did the amniotic folds (Fig. 140). It therefore lines the whole internal surface of the investing membrane of the ovum with a flattened vascular sac, the vessels of which come from the interior of the body of the embryo. The cavity of the allantois is continuous with the cavity of the intestines. The umbilical vesicle is situated between the amnion and allantois. In the chick the allantois comes immediately in contact with the shell membrane, taking the place of the albumen which has been liquefied and absorbed; and through the pores of the shell an interchange of gases takes place, oxygen being absorbed from the air, and carbonic acid exhaled from the blood-vessels of the allantois. It will be seen, therefore, that a true respiration takes place by means of the allantois through the external covering. When the chick arrives at maturity, it breaks open the shell and escapes from its confinement; the allantoic vessels are torn off at the umbilicus, and the allantois remains behind in the abandoned egg shell.

Fig. 140.

Formation of the allantois:—*a*, inner layer of amnion; *b*, outer layer of amnion; *c*, amniotic cavity; *d*, vessels of the allantois; *e*, umbilical vesicle.

Formation of the Chorion.—In the human embryo the obliteration of the cavity of the allantois takes place very early, so that it does not enclose a cavity, but fuses together, and uniting with the outer fold of the amnion and the vitelline membrane, constitutes the *chorion*. Hence there are two membranes in the fœtus, the *amnion* and the *chorion*, and the umbilical vesicle is situated between the two. The chorion in the human subject is identical with the allantois of the lower animals, its chief peculiarity being that its opposite surfaces are adherent instead of enclosing a cavity. The next peculiarity of the chorion is that it becomes shaggy, owing to the number of minute *villi* or "villosities" which are found on its surface (Fig. 139). The villi may be distinctly seen as soon as the ovum has reached the uterine cavity, even when it is still very small. They continue to grow and elongate, and divide into a number of branches by the process of sprouting, each filament terminating in a rounded extremity. The whole tuft bears a certain resemblance to some varieties of seaweed. The vessels of the chorion pass into the villosities, forming loops like the vessels in the villii of the small intestine. The villi of the chorion therefore bear a slight resemblance to those of the small intestine; but are unlike any other structure of the body, and their presence in the uterus or its discharges may be considered as a *proof of pregnancy*.

Fig. 141.

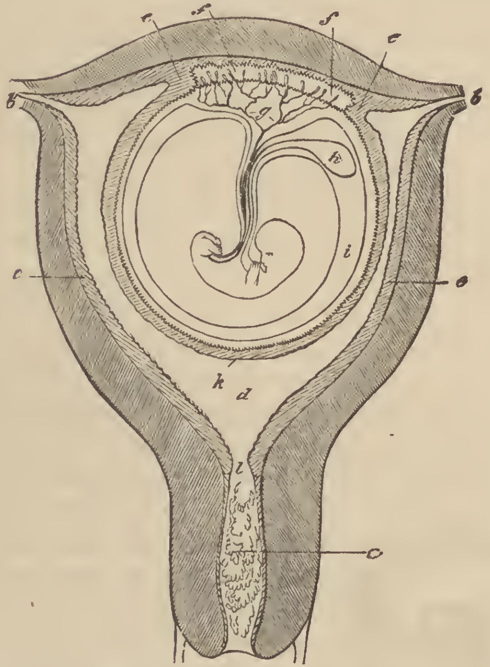
The human ovum at about the third month, showing the enlargement of the cavity of the amnion, the formation of the placental portion of the chorion, the commencing formation of the umbilical cord, and the atrophy of the umbilical vesicle.

The villi are the organs through which nourishment is supplied from without, at this stage of existence. At about the end of the second month the villi become atrophied, except at the part which corresponds with the insertion of the fœtal vessels, and the chorion becomes partly *bald* (Fig. 141). Those villi which

remain, continue to grow, and ultimately form the placenta, which attaches itself to the uterus (Fig. 142).

PREPARATION OF THE UTERUS TO RECEIVE THE OVUM.—As the impregnated ovum is about to descend into the cavity of the uterus, the mucous membrane becomes greatly

Fig. 142.



Vertical section of the womb, containing a developed ovum; *a*, neck, filled with a gelatinous plug; *bb*, orifice of the Fallopian tubes; *cc*, decidua vera; *d*, uterine cavity, almost entirely filled with the ovum; *ee*, decidua vera continuous with the decidua reflexa; *f*, placenta; *g*, allantois; *h*, umbilical vesicle and its pedicle in the umbilical cord; *i*, amnion; *k*, decidua reflexa and chorion.

hypertrophied, tumefied, and vascular, and projects in rounded eminences into the uterine cavity. The tubules or follicles are elongated, and enlarged so that their open mouths may be seen with the naked eye. The hypertrophied mucous membrane is called the *decidua vera.* When the ovum reaches the uterus it insinuates itself between the opposite surfaces of the mucous membrane, and becomes lodged in

one of the depressions between the projecting eminences of the decidua, where it subsequently becomes fixed. At this point a rapid development of the mucous membrane takes place, and a folding or prolongation of the decidua surrounds and envelopes the ovum, called the *decidua reflexa.*

It was formerly supposed that the decidua was an entirely new product, thrown out by exudation from the surface of the uterus, similar to the inflammatory exudation of croup, etc., which surrounded the whole internal surface of the uterus, and was called the *decidua vera.* As the ovum passed from the Fallopian tube into the uterus it pushed before it a folding of the decidua vera, which formed the *decidua reflexa.* The closure of this folding behind the ovum, was called the *decidua serotina.* This was the theory of William Hunter. It is now known to be no other than the mucous membrane itself, very much thickened and hypertrophied.

FORMATION OF THE PLACENTA.—The placenta is formed partly by the vascular tufts of the chorion, and partly by the hypertrophied mucous membrane to which they are connected. About the commencement of the third month, the villi which are destined to enter into the formation of the placenta continue to elongate, and penetrate or are pushed into the follicles of the mucous membrane, (like the fingers into a glove), which are enlarged for their reception. The growth of the villi and that of the follicles go on simultaneously, and keep pace with each other. The capillaries of the villi are enlarged and become tortuous, and those on the exterior of the follicles enlarge excessively and become dilated into wide *sinuses,* which are filled with blood derived from the arteries of the uterus, so that two membranes intervene between the capillaries of the villi and the sinuses of the uterus, viz., the covering of the villi and the lining membrane of the follicles. These afterwards fuse together and blend with the walls of the capillaries on the one hand, and the walls of the sinuses on the other. The tufts of the villi

are prolonged into the sinuses, pushing before them the walls, and are everywhere bathed with the blood of the mother. The process of osmosis takes place through the thin fused membrane, there being no direct communication between the fœtal and maternal vessels. The placenta is fully formed about the commencement of the fourth month, and constitutes the channel through which nourishment is conveyed from the mother to the fœtus. The nutritive material passes from the blood of the mother through the intervening membrane by *osmosis*, and enters the blood of the fœtus. Besides, the placenta is an organ of exhalation as well as of absorption. The impurities circulating in the blood of the fœtus are here discharged into the maternal vessels, to be removed by the excretory organs of the mother; so that the placenta may be said to fulfil the double office of the lungs and stomach in the fœtus. In consequence of the intimate relation existing between the mother and the fœtus, there is no doubt that nervous impressions experienced by the former, such as fear, anger, disgust, etc., which disturb the circulation, may occasion deformities and deficiencies of various kinds, nævi, warts, etc., in the latter. The circulation in the fœtus has been already described (p. 227).

Umbilical Cord and Amniotic Fluid.—The umbilical cord, or funis, is the connecting link between the fœtus and placenta. In early life it is very short, and consists of that portion of the allantois or chorion next the abdomen. The umbilical vesicle is situated between the amnion and chorion, the rest of the space being filled with a gelatinous fluid. The amnion continues to expand, the quantity of liquor amnii increases, and about the beginning of the fifth month the amnion comes in contact with the chorion, the umbilical vesicle and gelatinous fluid gradually disappearing. The umbilical cord at the same time elongates in proportion to the increasing size of the amnion, and towards the close of gestation the amnion and chorion blend together and constitute what is commonly called the "membranes." As the

cord lengthens it twists from right to left. It consists of the two umbilical arteries, the umbilical vein, the urachus, and the remains of the umbilical vesicle, imbedded in a gelatinous material (Whartonian jelly) and surrounded by a folding of the amnion. The cord at full term varies in length from one to three feet.

PARTURITION.—The discharge of the fœtus is termed parturition. This is effected by the contraction of the muscular fibres of the uterus, assisted in the second stage by the contraction of the diaphragm, abdominal, and other muscles of the body. The placenta is separated from its attachment to the inner surface of the uterus, during which the sinuses are lacerated and a certain amount of hemorrhage occurs, which, however, is soon arrested by the contraction of the uterus and consequent closure of the mouths of the vessels leading to the sinuses.

Fig. 143.

Muscular fibre cells of the uterus two weeks after parturition.

After parturition the uterus undergoes the process of *involution.* This consists of a diminution in the size of the uterus, and a change in the appearance of the muscular fibre cells. The muscular fibres of the uterus, during gestation, are very much increased in size, and granular in appearance. After parturition they appear to undergo a fatty degeneration; fat globules make their appearance in the interior of the muscular fibre cells; the tissue becomes soft and is gradually absorbed, its place being supplied by new cell fibres.

GENERAL DEVELOPMENT OF THE EMBRYO.

The development of certain parts of the body from the blastoderm, has been already casually referred to. The several organs, and systems of organs will now be considered in their order of succession.

DEVELOPMENT OF THE SPINE, CRANIUM AND NERVOUS SYSTEM.—The epiblast as has been already stated, rises up in the form of plates, and encloses the medullary or spinal canal (Fig. 137). Beneath this in the mesoblast is formed the chorda dorsalis, or notochord, and at each side the protovertebræ which increase in size and grow up around the notochord and form the spine. The spinal canal becomes enlarged anteriorly, corresponding to the brain, and terminates by a pointed extremity. The cranium is developed from the protovertebræ, surrounding the upper extremity of the chorda dorsalis. At the same time a growth of nervous matter takes place in the interior of the canal. At first the canal has an oval shape on section, and presents an elongated slit, but presently the opposite sides unite in the centre, forming the gray commissure and dividing it into an anterior and posterior portion ; the former becomes the central canal, and the latter forms the posterior fissure. The anterior fissure is formed by an inward folding of the anterior part. At this stage the cord consists chiefly of gray matter. White matter is now developed from the cells of the mesoblast, and covers the outer surface dipping into the bottoms of the fissures to form the commissures. The anterior bulbous enlargement, or brain, separates into three portions, the *cerebral vesicles,* anterior, middle and posterior, from which the different portions of the encephalon are developed. The anterior, forms the hemispheres and optic thalami, the middle, the corpora quadrigemina, and the posterior, the cerebellum and medulla oblongata. At this period the size of the different parts of the encephalon is different from the same organs in the adult ; *e. g.* the hemispheres are only slightly larger than the corpora quadrigemina, and the cerebellum is smaller

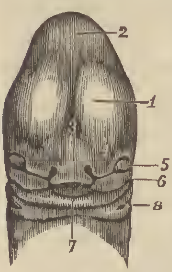
Fig. 144.

The spine at an early age showing the anterior dilatation and protovertebræ ; 1, 2, 3, anterior, middle, and posterior cerebral vesicles ; a, slight flattening of the anterior vesicle ; b, protovertebræ ; c, lumbar enlargement ; o, optic vesicle (Longet).

than the medulla oblongata. As development proceeds, however, the relative size of the different parts soon changes, convolutions begin to make their appearance, and the hemispheres are divided by the longitudinal fissure.

DEVELOPMENT OF THE FACE.—As the cerebral extremity of the fœtus becomes developed, it bends forwards upon its axis and forms the cerebral and frontal prominences and *four* depressions, the cervical fissures. Between the fissures are four foldings or arches, called the visceral or *pharyngeal arches*, in which are developed the bones of the face. Between the first pharyngeal arch and the frontal prominences, is the opening of the mouth. The *first* pharyngeal arch divides into a superior and an inferior protuberance on each side; the latter unites very soon with its fellow of the opposite side to form the lower jaw. The superior protuberances which form the upper jaw unite in the median line, with the fronto-nasal or intermaxillary process. The growth of these parts diminishes the size of the oral cavity; a lamella grows inwards from the superior maxillary tuberosity, joins the one from the opposite side and forms the palatine arch. If from any cause, the superior maxillary and intermaxillary processes fail to unite with each other, *hare-lip* or *cleft palate*, or both, are the result. This serves also to explain why hare-lip is always on either side of the median line, single or double; in the latter case the intermaxillary process which contains the incisor teeth is frequently detached from the superior maxilla, and is adherent to the nose. Cleft palate is caused by a deficiency in the union of the the lamellæ which form the palatine arch. The soft palate may be cleft also. The *second* pharyngeal arch forms the stapes, stapedius muscle, pyramid, styloid process, styloid ligaments and the lesser cornu of the hyoid bone; from the

Fig. 145.



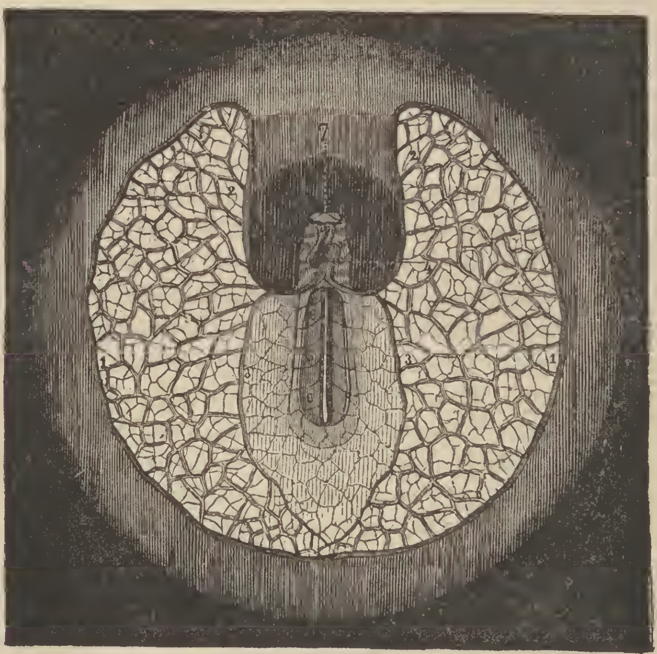
Head of a human fœtus at the 5th week; 1, frontal prominences; 2, cerebral prominences; 3, fronto-nasal process; 4 lateral frontal process; 5, eye; 6, superior maxillary process; 7, lower jaw; 8, ear; (Ecker).

third is formed the greater cornu and body of the hyoid bone; and from the *fourth*, the soft parts of the neck. The cervical fissures all disappear in a short time except the first, which forms the meatus auditorius, Eustachian tube and tympanic cavity.

Development of the Eye, Ear and Nose.—The *eye* is formed from the primary *optic vesicle*, an outgrowth from the first cerebral vesicle (Fig. 145.) It is at first an open cavity communicating by a hollow stalk with the general cerebral cavity, but as development proceeds it is filled up and becomes the optic nerve. The lens is formed by a thickening of the epidermic layer, and is received into a depression in the primary optic vesicle. After a time a secondary cavity is formed behind the one for the lens, in which the vitreous humor is secreted. The lens is at first surrounded by a vascular capsule, connected with the arteria centralis retinæ, and forms the membrana pupillaris. Vessels pass into the ball and form the choroid coat. The epithelium of the cornea is developed from the epiblast, and the cornea and the sclerotic are developed from the mesoblast. The iris is formed from a projection of the choroid. The pupil is at first closed by the membrana pupillaris, but it disappears in the human fœtus about the seventh month. The *ear* is developed in the form of a vesicle, the primitive *auditory vesicle*, on the outside of the third cerebral vesicle over the second pharyngeal arch (Fig. 146, 8). The cavity of the vesicle forms the internal ear, and the auditory nerve is formed from the mesoblast which unites the cerebral with the auditory vesicle. The middle ear and Eustachian tube are formed from the first pharyngeal fissure, and the tympanum from a membrane stretched across the fissure. The pinna is formed from the soft parts of the first pharyngeal arch, and the ossicles from the second pharyngeal arch. The *nose* arises from a depression in the epiblast at each side of the fronto-nasal process, the *olfactory fossæ*. These deepen except at the lower part where they

lead by the olfactory groove into the cavity of the mouth. After the formation of the palatine arches, this cavity is divided into two parts; the lower forms the mouth; the upper, divided by a septum, the nose. The olfactory nerve is derived from a prolongation of the anterior cerebral vesicle.

Fig. 146.



Area vasculosa of an embryo, ventral surface. 1, Terminal sinus. 2, Omphalo-mesenteric vein. 3, Its posterior branch. 4, Heart in the form of an S. 5, Primitive aorta, or posterior vertebral arteries. 6, Omphalo-mesenteric arteries.—*Bischoff.*

Development of the Extremities. — The upper and lower limbs are formed as buds from the anterior and posterior part of the embryo, by a projection of the somatopleure covered by the epiblast. The division of the extremity of these buds into fingers and toes, which have a webbed appearance, takes place at an early period, and soon after, a constriction or groove marks the situation of the wrist-joint. As growth proceeds another groove shows itself, at the elbows

and knees. In all animals, the anterior extremities precede the formation of the posterior.

Development of the Vascular System.—The vascular system assumes three different forms during different periods of life, viz., the *vitelline, placental,* and *complete.* The vitelline circulation commences at a very early period in the chick, and consists of a number of vessels which ramify over the surface external to the embryo, and form a plexus, the "area vasculosa." The vessels are formed from the cells of the mesoblast, which become elongated, or branched, unite with each other and become hollowed out to form the capillary walls (p. 222). The blood corpuscles are formed from the nuclei of these cells. The function of this structure is to absorb the nutrient material from the vitellus. About this time the heart begins to make its appearance. This organ and the larger blood-vessels are formed on the same plan. Masses of embryonic cells of the splanchnopleure are arranged in the position, form and size of the developing structures; the external layers of cells are converted into the walls of the organs and the internal form the first blood corpuscles (p. 174). The heart may now be seen as a minute red pulsating point, even before the muscular fibres have been formed; this is the "punctum saliens" of Harvey. The heart is at first tubular in form, and receives posteriorly the two omphalo-mesenteric veins, and opens anteriorly into the primitive aorta, which divides into two vessels, the *vertebral arteries.* These form a series of arches, and give off the two omphalo-mesenteric arteries to the area vasculosa. It then becomes curved or bent upon itself like the letter S or a horse shoe, and partly divided by constrictions into three cavities. The one corresponding with the arterial end, is the bulbus arteriosus; the one at the venous end, the auricle; and the one in the middle is the ventricle, which becomes more rapidly developed than the others. In some animals,

Fig. 147.

Heart of the chick at the third day of incubation —1, the veins; 2, the auricle; 3, the ventricle; 4, the bulbus arteriosus.—*Thompson.*

as the Amphibia, this form remains, no other division by septa taking place; but in the higher animals and man, both auricle and ventricle are subdivided by septa, and the bulbus arteriosus disappears in the ventricles.

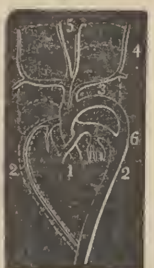
In man and the higher animals in which the vitellus is small, the vitelline form of circulation soon disappears, and is replaced by the *placental* or *allantoic circulation.* The two omphalo-mesenteric arteries become blended into one artery, and the corresponding veins into one vein. They are called omphalo-mesenteric arteries because they supply in part the "omphalos" or umbilical vesicle, and partly the mesentery and intestine. After a time the umbilical vesicle and its vessels diminish, the mesenteric vessels increase, and the allantois grows out from the posterior part of the intestinal cavity, carrying with it the allantoic or placental vessels. There are two *umbilical arteries* and at first two corresponding veins, but after a time one of the veins disappears, and the whole of the blood is returned from the placenta by one vein.

The *complete* circulation takes the place of the placental circulation, which is abruptly terminated by the separation of the placenta at birth. This transition is more abrupt than the preceding; but has been duly provided for by the gradual development of the necessary organs.

The *blood vessels* first commence to form, as previously stated, in the area vasculosa external to the body of the embryo. The first aortic arch is formed by the division of the primitive aorta into two branches, which arch backwards, and, after descending, unite into one vessel in front of the vertebral column (Fig. 148). Other pairs of arches are formed in succession behind the first, to the number of five. These are not all to be seen at the same time, for as some develope, others disappear. In fishes they all persist through life and form the distribution as seen in the gills. In man and the higher animals, the anterior ones disappear and the posterior ones become transformed into the carotids (5),

subclavian (4), arch of the aorta, pulmonary artery, ductus arteriosus, and descending aorta (Fig. 148). The *veins* that first appear are, as already stated, the omphalo-mesenteric which soon unite to form one. Next is formed the two umbilical veins, which return the blood from the placenta, the left enlarging, while the right disappears. When the liver begins to be formed branches pass into that organ, and give origin to the hepatic veins. This organ receives blood from two sources, the portal, and the umbilical veins. The systemic veins are formed from *four* trunk veins, two above, and two below, which unite into a canal (sinus of

Fig. 148.



Aortic arches; five pairs are shown, the upper ones disappear, the three lower remain, and represent the carotids (5), the subclavian (4) and arch of the aorta (3). 1, Trunks which spring from the ventricles; 2, descending aorta, the left (2) is finally obliterated; the ductus arteriosus is seen at the junction of the arch with the descending portion (6).

Fig 149.

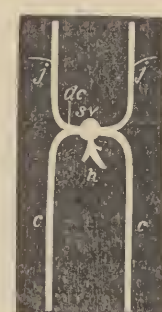


Diagram of the development of the veins: c, c, cardinal veins; j, j, jugular veins; h, hepatic veins; dc, ducts of Cuvier; sv, sinus venosus.

Cuvier) on each side, and open into the rudimentary auricle. (Fig. 149). The two above are called the anterior cardinal, or jugular veins, and the two below are called the posterior or inferior cardinal veins. When the umbilical vein is formed, it at first communicates with the sinus of Cuvier, but after the inferior vena cava is developed, it empties into the latter. The auricle now receives blood from the inferior vena cava, and the sinuses of Cuvier which now become the right and left superior vena cava respectively. The left vena cava finally disappears and its

orifice is converted into the coronary sinus ; the right, forms the superior vena cava. An anastomosing branch between the anterior jugular veins becomes the left innominate, and the termination of the right jugular the right innominate vein. The inferior cardinal veins return the blood from the Wolffian bodies, vertebral column, and parietes of the trunk. The inferior vena cava is formed about the fifth week, and finally receives the blood from the inferior cardinal, and the crural veins. The upper part of the cardinal veins remains, the right one as the vena azygos major, and the left as the vena azygos minor and superior intercostal. The middle portion disappears, and the lower becomes the hypogastric.

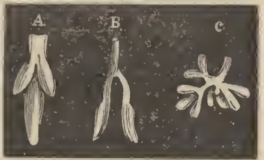
Development of the Alimentary Canal and Glands. —The alimentary canal is formed at a very early stage. It is at first closed at each end, by the blastodermic layers, and communicates with the umbilical vesicle. It consists of three parts ; the anterior, which forms the pharynx and œsophagus ; the middle which forms the stomach, intestines, and upper third of the rectum ; and the posterior which forms the middle third of the rectum. The lower end of the rectum and buccal cavity are formed by a depression in the middle and external layers of the blastoderm, and do not communicate with the common cavity till a later date, hence the occasional occurrence of imperforate anus and imperforate œsophagus. The middle portion of the intestine, is at first a wide groove, which becomes converted into a straight tube, and is gradually separated from the umbilical vesicle. It now becomes divided into the different parts, as the stomach, small intestine, and large intestine, and is suspended in the abdomen by the mesentery which attaches it to the spine.

The principal glands are the *liver, pancreas, spleen* and *salivary glands.* The liver is developed from two prominences of the blastoderm in the form of hollow cones, which involve the omphalo-mesenteric vein, from which they re-

ceive branches. These prominences are developed into the right and left lobes. This organ is of large size in proportion to the body, and secretes a substance which is poured into the intestine, termed the meconium. The gall bladder is developed as a pouch from the hepatic duct. The salivary glands are developed from the epiblast lining the mouth, in the form of simple canals with bud-like processes, surrounded with protoplasm and communicating with the mouth. The canal becomes more ramified as development proceeds. The pancreas is developed from the hypoblast lining the intestine, in a similar way, and the spleen is developed from the mesoblast, proceeding from a segment of the peritoneum.

Development of the Respiratory Organs. — The lungs first appear as small tubercles in front of the œsophagus. They are formed from the hyyoblast of the alimentary canal. They at first open into the œsophagus, but, soon a separate tube is formed at their point of junction ; this is the trachea. The primary tubercles thus formed next send off secondary branches into the surrounding mesoblast, and these again tertiary ones on which the air cells are formed. The diaphragm appears early, in the form of a fine membrane separating the lungs from the Wolffian bodies, stomach and liver.

Fig. 150.



A, B, development of the lungs; C, tertiary branches and air cells.

Development of the Urino-sexual Organs.—These organs are formed from the mesoblast. The Wolffian body or primitive kidney may be seen as early as the third week. It has a glandular structure, in many respects similar to the kidney, is provided with an excretory duct, and secretes a fluid containing urea which is conveyed to the bladder. It attains its highest development. about the sixth week ; it then diminishes, to be replaced by

the kidney, iby ppdad sanears the end of the third month The duct of the Wolffian body is formed in the mesoblast behind the pleuro-periconeal cavity. The duct is first hollowed out, and then the tubes of the Wolffian body begin to form as branches of the duct which terminate in Malpighian bodies. Next a thickening occurs between the Wolffian body and the mesentery, termed the Wolffian ridge or "germ epithelium" from which the testis or the ovary is developed, as the case may be. A groove is now formed internal to the Wolffian duct, called the duct of Müller. These ducts, together with the ureter, when formed, open into the urogenital sinus, or termination of the intestinal cavity. The Wolffian ducts remain in the male, and form the epididymus, vas deferens and ejaculatory duct on each side. A small portion of the Wolffian body remains in the female termed the *parovarium*, while the remains of the Wolffian duct which descends to the vagina forms the "duct of Gærtner." The ureter is formed in the mesoblast in which the kidney commences to develope, and leads down to the urachus. The kidney is developed from a series of club-shaped mases, in which are formed the calices. It has therefore a lobulated appearance which continues for some time. The supra-renal capsules are developed from the same mass as the kidney, and are at first much larger.

Fig. 151.

A, kidney ; B, ureter ; C, Bladder ; D, urachus ; E, constriction which becomes the urethra ; F, Wolffian body ; G. Wolffian duct, with its opening below, G'; H, duct of Müller, united below, from the two sides, into a single tube, J', which presents a single opening. J, between the openings of the Wolffian ducts ; K, ovary or testicle ; L, gubernaculum testis or round ligament of the uterus ; M, genito-urinary sinus ; N, O, external genitalia.

The bladder is next developed from the *urachus;* this is a hollow tube which connects the posterior part of the intestines with the allantois. As the abdomen closes at the umbilicus, the part of the urachus outside the body forms part of the cord, while the portion included in the abdomen becomes dilated and fusiform at the lower part, and forms the bladder; the upper part becomes obliterated and forms a fibrous cord which extends from the summit of the bladder to the umbilicus. Sometimes, though very rarely, this part remains pervious and permits of the escape of urine at the umbilicus. The testes or ovaries which are formed on the inner side of the Wolffian bodies, soon begin to descend, the former to the scrotum and the latter to the pelvis. This was formerly supposed to be caused by the action of a muscular organ, the gubernaculum testis, but this is not now g nerally supposed to be the case. The means by which it is effected are not known. The testicle in its descent pushes before it a pouch of peritoneum, behind which it lies, which ultimately forms the tunica vaginalis or serous covering of the testicle.

The uterus, Fallopian tubes, and vagina are developed from the ducts of Müller, already described. The union of the two ducts below form the vagina, cervix, and lower portion of the uterus, while the upper portions form the upper part of the uterus and Fallopian tubes. This explains the occurrence of an occasional bicornute condition of the uterus. The external organs of generation are, at an early stage, the same in both sexes. The urino-genital opening, or sinus, is formed at the same time as the anal cavity, by a reflection of the epiblast inwards. There is first seen a tubercle in front of the sinus, the *genital tubercle,* which is soon surrounded by two folds of integument, the *genital folds.* The tubercle is surmounted by a glans, and is grooved upon the under surface (Fig. 151), yet no distinction of sex can be made out. As development proceeds, the urino-genital sinus in the female remains and communicates with

the vagina; the genital tubercle retracts and forms the clitoris, and the foldings of integument are converted into the nymphæ and labia majora. In the male, the genital tubercle elongates, the glans is developed, and the margins of the sinus meet on the under surface to enclose the urethra. The large cutaneous folds form the scrotum, which receives the testicles about the eighth month. When the urethra fails to close, *hypospadias* results, and an appearance of hermaphroditism is present, which is increased by the retention of the testicles in the abdomen.

APPENDIX.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

	Equivalents.			
Metre	39.37	or	$39\frac{2}{5}$	inches.
Decimetre	3.93	or	$3\frac{3}{4}$	"
Centimetre	.39	or	$\frac{2}{5}$	"
Millimetre (mm)	.039	or	$\frac{1}{25}$	"
Micromillimetre (mmm)	.000039	or	$\frac{1}{25000}$	"

Gramme	15.43	or	$15\frac{1}{3}$	grains.
Decigramme	1.54	or	$1\frac{1}{2}$	"
Centigramme	.154	or	$\frac{1}{6}$	"
Milligramme	.015	or	$\frac{1}{65}$	"

THE METRIC SYSTEM IN MEDICINE.

Old Style.		Metric.
♏i or gr.i equals		06 gms.
fʒi or ʒi "	4	"
f℥i or ℥i "	32	"

The decimal line instead of points makes errors impossible. A teaspoon contains 4 gms. ; a tablespoon 20 gms.

AVERAGE SIZES OF VARIOUS HISTOLOGICAL ELEMENTS.

Fractions of an inch.	Metric.	
Air Cells $\frac{1}{70}$ to $\frac{1}{200}$	.3 to .12	mm
Blood Corpuscles, Red, $\frac{1}{3500}$	7.1	mmm
" " White $\frac{1}{3000}$	8	mmm
Canaliculi of Bone $\frac{1}{18000}$	1.4	mmm
Capillaries, $\frac{1}{3000}$	8	mmm
Cartilage Cells, $\frac{1}{450}$ to $\frac{1}{2000}$	55 to 12	mmm
Chyle Corpuscles, $\frac{1}{3000}$	8	mmm
Cilia $\frac{1}{4000}$ to $\frac{1}{5000}$	6 to 5	mmm
Cones of Retina, $\frac{1}{12000}$	2	mmm
End-bulbs of Krause, $\frac{1}{600}$	41	mmm

Epithelium, Columnar, $\frac{1}{2500}$ to $\frac{1}{3600}$	10 to 7.1 mmm
" Squamous $\frac{1}{500}$ to $\frac{1}{2500}$	50 to 10 mmm
Fat Cells, $\frac{1}{300}$ to $\frac{1}{800}$	83 to 31 mmm
Granules, $\frac{1}{10000}$ to $\frac{1}{25000}$	2.5 to 1 mmm
Haversian Canals, $\frac{1}{200}$ to $\frac{1}{2000}$	120 to 12 mmm
Lacunæ (bone), $\frac{1}{1800}$	14 mmm
Limbus Luteus, $\frac{1}{25}$	1 mm
Malpighian Bodies, (kidney), $\frac{1}{120}$	.2 mm
" " (spleen), $\frac{1}{60}$	.4 mm
Muscle, Striated, $\frac{1}{200}$ to $\frac{1}{500}$	125 to 50 mmm
" Nonstriated, $\frac{1}{3000}$ to $\frac{1}{4500}$	8.5 to 5.5 mmm
Nerve Cells, $\frac{1}{300}$ to $\frac{1}{1000}$	83 to 2.5 mmm
" Fibres, (medullated) $\frac{1}{2000}$ to $\frac{1}{12000}$	12 to 2 mmm
" " (non-medullated) $\frac{1}{4000}$ to $\frac{1}{6000}$	6 to 4 mmm
Ovum, $\frac{1}{120}$	.2 mm
Pacinian Bodies, $\frac{1}{10}$ to $\frac{1}{15}$	2.5 to 1.7 mmm
Papillæ of Skin, $\frac{1}{100}$ to $\frac{1}{250}$	.25 to .1 mm
" of Tongue, $\frac{1}{12}$ to $\frac{1}{70}$	2 to .3 mmm
Tactile Corpuscles, $\frac{1}{250}$	.1 mm
Tubuli Uriniferi, $\frac{1}{500}$	50. mmm
Villi, $\frac{1}{50}$ to $\frac{1}{250}$	.5 to .1 mm

AVERAGE SPECIFIC GRAVITY OF VARIOUS FLUIDS.

(Water = 1000).

Bile	1020	Milk	1025
Blood	1055	Pancreatic Juice	1012
Cerebro-Spinal Fluid	1006	Saliva	1005
Chyle	1024	Serum	1026
Gastric Juice	1005	Sweat	1004
Intestinal Juice	1011	Urine	1020
Lymph	1020		

Lungs when fully distended with air, 126; when deprived of air, 1056; ordinary postmortem condition, 345 to 746.

AVERAGE QUANTITY OF VARIOUS FLUIDS SECRETED IN TWENTY-FOUR HOURS.

	ozs.	gms.		ozs.	gms.
Bile	35 =	1100	Saliva.	30 =	930
Gastric Juice	240 =	7500	Sweat.	25 =	780
Pancreatic Juice.	14 =	440	Urine	40 =	1250

REACTION OF THE VARIOUS FLUIDS.

All the fluids of the body have an alkaline reaction, except the following, which are acid :

Gastric Juice.	Urine.
Sweat.	Mucus of the Vagina.

CLASSIFICATION OF THE ANIMAL KINGDOM.

(Gegenbauer.)

INVERTEBRATA.

Protozoa :
- Rhizopoda ; amœbæ, foraminifera.
- Gregarinæ.
- Infusoria ; vorticella, paramæcium.

Cœlenterata :
- Spongiæ ; sponges.
- Acalephæ ; hydra, coral, sea-anemone, polyps, medusæ, beroe.

Vermes : leeches, earth worm, round worm, thread worm, tape worm, guinea worm, bryozoa.

Echinoderma : star-fish, sea-urchins, sea-cucumber.

Arthropoda :
- Branchiata ; crab, lobster, barnacle.
- Tracheata ; scorpion, spider, beetle, cockroach, bee, ant, butterfly.

Brachiopoda :
- Ecardines ; lingula.
- Testicardines ; terebratula.

Mollusca :
- Placophora ; chiton, cryptochiton.
- Conchifera ; oyster, cockle, whelk, snail, clio, argonaut, cuttlefish, nautilus.

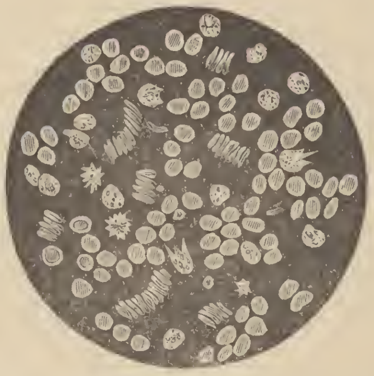
Tunicata :
- Copelata ; oikopleura.
- Acopa ; salpa, pyrosoma.

VERTEBRATA.

Acrania : Leptocardii ; amphioxus.

Craniota :
- Cyclostomata ; myxinoidea, petromyzontes.
- Gnathostomata.
  - *(a) Anamnia :*
    - Pisces.
    - Amphibia ; frog, newt, triton, salamander.
  - *(b) Amniota :*
    - Reptilia ; lizard, snake, crocodile, chameleon, tortoise.
    - Aves.
    - Mammalia.

ADDENDUM.



Specimen of blood showing marked leucocythæmia. The proportion of white to red corpuscles is as one to seven.

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